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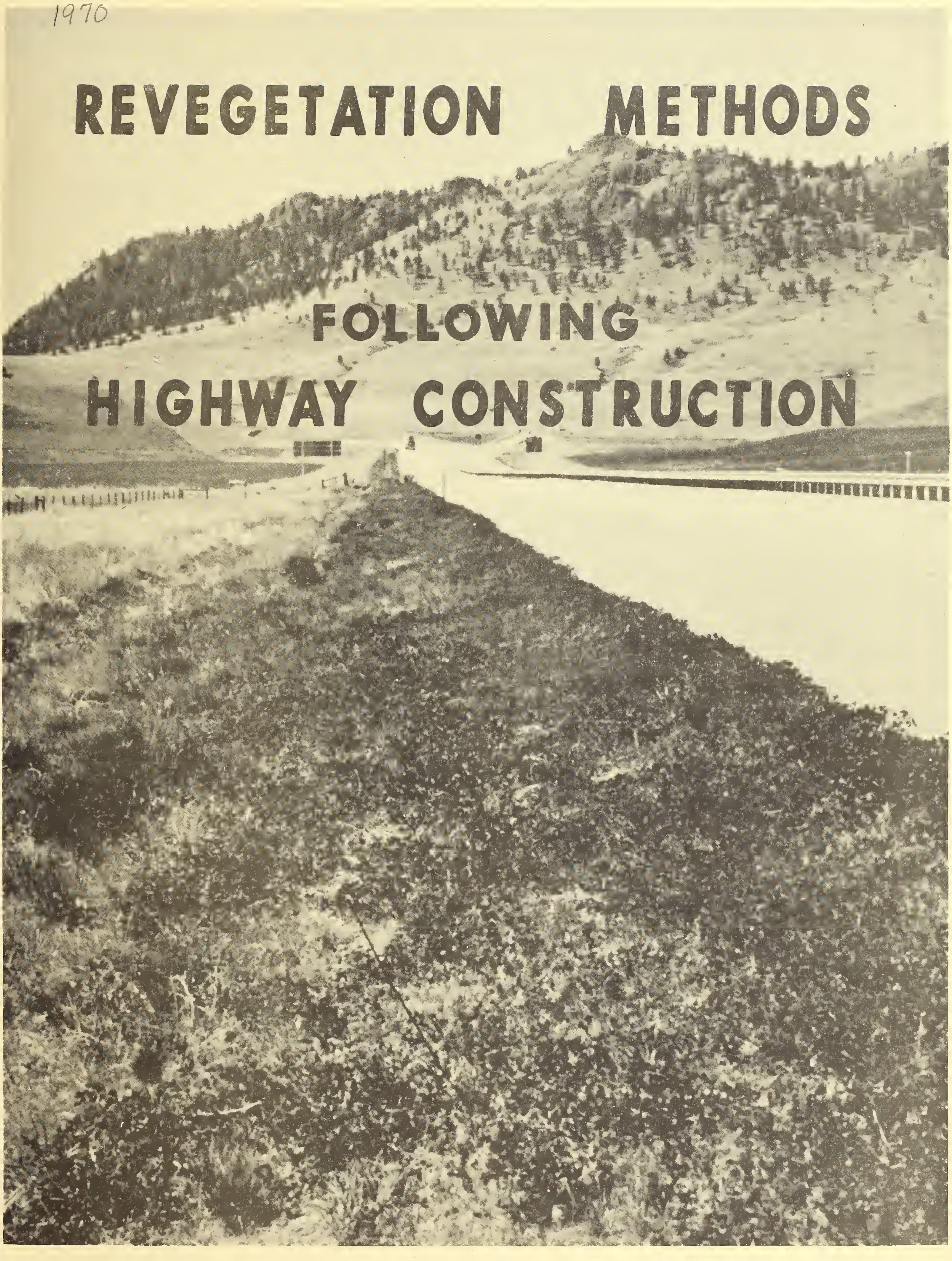
REVEGETATION METHODS FOLLOWING HIGHWAY CONSTRUCTION



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FINAL REPORT

REVEGETATION METHODS AND CRITERIA FOR BARE AREAS FOLLOWING HIGHWAY CONSTRUCTION

For the

Montana State Highway Commission
Planning Survey Section

In cooperation with the
U. S. Department of Transportation
Federal Highway Administration

By

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The opinions, findings and conclusions expressed in this publication are those of the author and not necessarily those of the Federal Highway Administration and the Montana State Highway Commission.

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R. L. Hodder

ABSTRACT

Methods and criteria for vegetation and practical stabilization of roadsides in Montana involve problems of broad scope, complexity and magnitude. Various facets of the roadside seeding and vegetation problem were studied in sequence at several research sites along Montana roadsides, each exploration indicating or substantiating a priority of study needs.

At the commencement of the research project, a roadside vegetation survey and a contract seeding evaluation study were conducted to provide a basis for the selection of initial studies concerning seeding and mulching. These investigations led directly to species selection tests, studies involving fertilizer requirements, and effects of fertilizer slurries on seed germination characteristics. Unsatisfactory performance of mulches promoted trials with experimental mulch binders which provided some unexpected advantages. The sensitivity of time-of-seeding under semi-arid growing conditions encouraged the testing of dryland planting innovations with both grasses and shrubs, and led to the development of dryland planting of shrubs in "tubelings" and in "condensation traps".

These exploratory studies indicate areas of concern within which, hopefully, future maintenance economies may be realized with a minimum of investment in time and money.

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SUMMARY

The Highway Revegetation Project presented in this report extended through a period of five and one half years. The overall project was composed of thirteen separate, and in some cases, relatively independent studies which are presented in this report as individual "jobs". In this summary, a brief resume of the purpose and pertinent results of each of the thirteen jobs is given.

JOB #1. ROADSIDE VEGETATION SURVEY

The initial roadside vegetation survey was conducted to obtain preliminary information needed for highway seeding programs. Nearly 4,000 points along Montana highways were examined in detail according to physiography, soil, erosion, and vegetation. The results emphasized the limitations of some species previously used for species selection and the relative benefits of a second seeding program.

JOB #2. CONTRACT SEEDING EVALUATION

The contract seeding evaluation was undertaken to determine the effectiveness of various past seeding attempts by contractors. Information from all available sources was accumulated on all contract seedings from 1960 to 1964. Because of extreme variability in species seeded, time of seeding, soil and weather conditions, and equipment used, no one seeding practice was shown to be superior. The findings of this study stress the need for standardization and maintenance of complete and accurate seeding records.

JOB #3. SEED GERMINATION STUDY

Seed germination studies provide essential information on available forage species and also on native species characteristics thought to have particular potential for highway seeding purposes. Tests were also made to determine the effects of hydroseeding with fertilizer slurries on seed germination. Results showed that fertilizer slurries may inhibit normal germination or development of roots and shoots. The lowest germination was obtained with a combination of agitation, pressure, and fertilizer similar to the characteristics of hydroseeder slurry. Extreme mechanical damage to some types of seeds was caused by hydroseeder action.

JOB #4. SOIL TEMPERATURE AND MOISTURE RELATIONSHIPS

A soil temperature and moisture study was designed to compare soil temperature and percent moisture as affected by various surface treatments. Based on this study, a straw and asphalt mulch was recommended to provide lower soil surface temperatures, maintain adequate moisture for seed establishment, and retard erosion.

JOB #5. INDIVIDUAL PLANT SPECIES EVALUATIONS

Species plots were set out at three locations in the state to evaluate the adaptability of various species to roadside conditions. The trials demonstrated the effectiveness of a number of species that have had little if any previous use on roadsides. Results also substantiated the importance of early seeding.

JOB #6. FERTILIZER EVALUATIONS

Fertilizer studies were conducted to provide information needed to design a practical fertilizing program for roadsides. The most productive combination of time of seeding and fertilizing was the earliest drilled seeding accompanied with the earliest broadcast fertilization. Late application of fertilizer appeared to be damaging.

JOB #7. SOIL INNOCULATION TRIALS

Tests were conducted with commercial soil innoculant materials to determine if bacterial innoculation of sterile highway slopes is beneficial or necessary in order to establish a rapid desirable cover. It was concluded that such bacterial products tested are not recommended for general use at this time.

JOB #8. EVALUATION OF MULCHES AND BINDERS

Twelve different treatments were evaluated in an effort to gain meaningful comparisons of various combinations of mulches and mulch binders. It was concluded that a carefully applied mulch of clean straw with asphalt binder is both an effective and economical mulching treatment for low-wind areas. A choice of two other mulching systems was recommended for windy areas. Two experimental chemical binders were found to be very effective.

JOB #9. TIME OF SEEDING

Two separate approaches were evaluated as possible means of extending the desirable time of seeding period in the spring. The first involved a mechanical manipulation of the soil surface with a deep furrow drill to create a pitted surface. This method proved to be unsatisfactory. The second approach involved the selection of species with characteristics which were especially adaptable to roadside conditions. Species testing has provided useful results and selection is still continuing.

JOB #10. NATIVE SHRUB PROPAGATION BY CUTTINGS

Native shrub propagation studies were undertaken to provide information which might encourage local nurseries to produce needed planting stock. Cuttings of forty native species were collected and subjected to various treatments prior to placement in a propagation bench, and propagation success was determined.

JOB #11. DRYLAND SHRUB PLANTING IN ELONGATED POTS

Evaluation of a new dryland shrub planting innovation which involved the development of plants as tubelings with forced elongated root systems produced survival ratings that exceeded controls. The study supports the possibility and practicality of a completely mechanized approach to shrub and tree planting on roadsides.

JOB #12. DRYLAND SHRUB PLANTING IN PLASTIC BASINS

Plastic covered basins (condensation traps) were designed as an innovation for dryland planting as a means of making subsurface soil moisture available to newly planted nursery stock. Temperature and condensation checks were made on both black and clear plastic covers. Useful information on basin design and practicability of the system was substantiated by survival percentages.

JOB #13. CHEMICAL MOWING WITH MALEIC HYDRAZIDE

A chemical mowing study was conducted to determine if such a program is feasible on Montana roadsides. The effect of the chemical on four common inslope grasses was analyzed according to culm incidence, height, and leaf height. Results varied widely by species. It was recommended that chemical mowing should not be used on grass mixtures on Montana roadsides.

As results became available throughout the duration of the project, they were presented in special reports, annual reports, slide presentations, workshops, annual highway tours, and in a roadside seeding and maintenance manual. A comprehensive slide series accompanied by a taped narration was produced and published under the title of, "The Role of Mowing in Roadside Maintenance." A second slide series was produced on the subject of erosion control as affected by roadside design and maintenance and was presented in modified versions at several conferences and to state highway maintenance personnel.

INTRODUCTION

The Highway Vegetation Project was initiated in May of 1964 with a scheduled termination date of December 31, 1968. The objectives of the research program were exploratory in nature and consisted of the following:

1. to define those conditions for which present vegetation practices are satisfactory, or for which additional vegetation efforts are not needed.
2. to develop methods of and machinery for vegetating roadside slopes.
3. to evaluate species of vegetation for roadside stabilization.
4. to develop a handbook of procedures and recommendations for the vegetation of bared soils on highway projects.

The original project was modified in the Fall of 1967 and extended for an additional year. This was considered necessary to broaden the scope of the study to include new regulations and techniques regarding roadside development. Implementation of these new practices presented problems far more crucial than those included in the original proposal.

Early in the study it became apparent that a knowledge of species adaptation and selection in combination with appropriate seeding techniques and practices was the basic and primary need for successful establishment of vegetation on dryland roadsides rather than the development of equipment to mechanize the planting or seeding process. To gain basic information on species capabilities, frequency, and location on roadsides within the State, two independent surveys were programmed for the first field season, (1) a roadside vegetation survey, and (2) a contract seeding evaluation. From these initial investigations evolved further more specific studies pertaining to seed germination; soil temperature and moisture on highway slopes; time of seeding; fertilizing; mulching; species adaptibility; and soil innoculation studies; and studies investigating various dryland planting techniques for shrubs. Each of the various studies is referred to by a "Job Number", and is presented separately in this report with a brief introduction followed by a section on procedures and results and conclusions.

The various research sites referred to in the studies in this report, and their approximate locations and climatological data are given in Table 1.

Table 1. Locations and climatological data for Highway Vegetation Research Sites.

Research Site	Approximate Location	Mean* Annual Precip. (in.)	Mean* July Temp. (°F)	Mean* Dec. Temp. (°F)
Townsend	6 miles east of Townsend on U.S. Highway 12	10.9	66	21
Roundup	20 miles south of Roundup on U.S. Highway 87	12.4	72	25
Cardwell	1/8 mile west of the Cardwell interchange, Interstate 90	11.3	69	28
Huntley	4 miles east of Huntley on Interstate 94	11.5	71	26
Bozeman	Vicinity of Bozeman, U.S. Highways 10 and 191.	17.4	66	25
Logan	Vicinity of Logan on Interstate 90	12.3	70	28

* Climatoligical data for Montana, Weather Bureau, U.S. Department of Commerce.

Job #1. ROADSIDE VEGETATION SURVEY

INTRODUCTION - The purpose of the initial roadside vegetation survey was to provide preliminary information pertaining to: 1) the scope and complexity of the roadside vegetation and stabilization problem, 2) the rate of development or natural successional change, and 3) the frequency of the various species of vegetation providing satisfactory stabilization of roadsides. It was felt that such basic information was necessary in order to provide efficient and profitable direction to more extensive studies.

PROCEDURES - The method of data collection used in this study consisted of a survey of roadside vegetation along four major routes throughout the state: two north and south, and two east and west. Data was obtained almost entirely from old road systems. Pertinent information affecting soil erosion and growing conditions was obtained at the end of each one-mile interval, excepting areas within city limits. A total of 3,798 sample location observations were used. Data were recorded on IBM Port-A-Punch cards to facilitate data acquisition, compilation and analysis. The survey format and questionnaire which was used for gathering data from the nearly 4,000 sampling locations is shown in Figure 1. Because of the broad variations in ecological types, data were first arranged according to 22 described vegetative zones for Montana. Not all of the vegetative zones were represented on roadside slopes studied and in several cases not enough data were represented within a particular vegetative zone to be usable. Following compilation of the data, species were ranked according to desirability as affected by vegetative zones, exposure, slope, and soil type. Data were arranged in tabular and graphic form for ease of crosschecking, interpretation and for making evaluations and projections for reseeding purposes.

Figure 1: Format for data collection.

Route number *1 *2 *3 *4	INTERVAL
Location * * * * * * * * * *	
* * * * * * * * * *	
* * * * * * * * * *	
* * * * * * * * * *	
*sideborrow *fill *cut	PHYSIOGRAPHY
*inslope *bottom *backslope	
*NW *W *SW *S *SE *E *NE *N	
*+ *110 *95 *80 *65 *50 *35 *20 *5	
*¼:1 *½:1 *3/4:1 *1:1 *2:1 *3:1	
*4:1 *5:1 *6:1 or less	
*adequate *inadequate *none	
*8000 *7 *6 *5 *4 *3 *2 *1	
*20 *15 *10 *5 *4 *3 *2 *1	
*unst. *rel.unst. *rel.st. *st.	SOIL
*sndy *slty *cly *shl *grv *rky	
*ocrp *mix *bnd	
A&B Hor. *15 *12 *9 *6 *3 *0	
*acid *neutral *alkaline	
*p.dry *t.wet *p.wet *t.dry *sbirr.	
*none *slight *moderate *severe	EROSION
*sheet *rill *gully *slide *flw	
*wnd *ovrflw *spring *seep *ppt	
*prgrs. *an.grs. *fbs *shb	VEGETATION
*trs *br.shd. *br. *an.wd.	
Banded *100 *80 *60 *40 *20 *0	
Sprcies #1	
Sprcies #2	
*seeded *invaded *both	
*desireable *undesireable	
*cult. *pastr. *nt.grs. *brsh	
*tmbr *yard	
*irrigated *non-irrigated	
*fenced *unfenced	
Veg. Zone * * * * * * * * * *	
* * * * * * * * * *	

Figure 2: **Roadside Evaluation Survey**

IBM Card Explanation

Route No. - (1) U.S.10 (2) U.S.2 (3) U.S.91 (4) U.S.87, 19, 191 and north from Malta to Canadian border on pavement.

Location - Card number, 2 for each stop on the mile, 1 mile beyond city limits, EVEN - right hand side, ODD - left hand side.

PHYSIOGRAPHY

Sideborrow - Roadside drainage with 5 feet limit in depth or height from road surface
Fill - more than 5 feet in depth from road surface
Cut - more than 5 feet in height from road surface
Inslope - slope from shoulder of road to bottom
Bottom - flat area between inslope and backslope
Backslope - slope from bottom toward R/W boundary
Exposure - direction slope is facing.
Length - length of inslope or backslope surface or total width of the sideborrow
Gradient - slope, or ratio or run:rise
Cover - degree of erosion control provided by veg. cover
Elevation - altitude from sea level
Estimated age - refers to the age of bank or portion of slope from which pertinent vegetation data is recorded.

SOIL

Stability - the degree to which a soil resists erosion because of vegetative cover
Class - texture of soil surface aspect
A & B Depth - total depth in inches of A & B horizon of surface soil at top of backslope
Reaction - soil reaction, pH of soil
Moisture - soil moisture
    Perm. Dry - no moisture
    Temp. Wet - usually dry
    Perm. Wet - always wet
    Temp. Dry - usually moist
    Subirrigated - refers to subsurface accumulation of moisture from adjacent irrigation
    Overflow - direct flow of water from adjacent irrigation or other source.

RESULTS & RECOMMENDATIONS - The state-wide tabulation of roadside data in Table 2 shows that 20% of the total samples involved slopes with a gradient of 6:1 or steeper; the remaining 80% of the samples were considered flat. Forty-five percent of the slopes were back slopes and 55% were in-slopes or fills. (By definition, a "slope" was considered to have a vertical elevational differential in excess of 5 feet from the pavement level; any roadside characteristic less than 5 feet in vertical measurement was placed in the "side borrow" category and was included among the "flat" group.) In this state-wide summation of slopes, the 1:1 (100% grade or 45°) gradient class was found to be the most common. One-third of all slopes were recorded in this class. These are extremely steep and typically unstable slopes. Less than one-fourth of all slopes were found in the 2:1 category, and less than one-fifth of the total were in the 3:1 class. Nearly 90% of all roadside slopes were 3:1 or steeper.

Based on these data, very steep cuts and fills are not the exception but rather the rule along old Montana highways. This does not necessarily mean that the roadsides were designed this way, but rather that erosion and maintenance practices over years of use have caused steeper roadsides to develop.

This general pattern was found to persist throughout all major vegetative zones encountered within the state. Even the most extensively sampled zone, the Central Grassland, had nearly one-third of the slopes included in the 1:1 or steeper category. It is true that in this relatively flat zone many of these difficult conditions were created during the road construction process by borrowing fill material from the narrow right-of-way, or aggravated by erosion or maintenance techniques, but they are

Table 2. All gradients of roadside slopes within vegetative zones including sideborrows.

Vegetative Zone	Percentages Based on Slopes 1:2:1 through 6:1								FLAT (Less Than 6:1)	SLOPE (6:1 or more)	TOTAL SAMPLES
	1/2:1	3/4:1	1:1	2:1	3:1	4:1	5:1	6:1			
Subalpine Forest	1	-	4	3	1	1	2	1	17	13	30
02	8%	-	31%	23%	8%	8%	15%	8%	57%	43%	
Larch Fir	7	9	55	45	27	37	17	1	148	198	346
03	4%	5%	28%	23%	14%	19%	9%	-1%	43%	57%	
Lodgepole -Douglas Fir	7	7	26	11	8	13	4	-	36	76	112
04	9%	9%	34%	14%	11%	17%	5%	-	32%	68%	
Western Ponderosa Pine	-	1	11	7	17	17	4	-	35	57	92
05	-	2%	19%	12%	30%	30%	7%	-	38%	62%	
Intermountain Valley Grassland	1	1	10	11	11	17	10	-	145	61	206
06	1%	1%	16%	18%	18%	28%	16%	-	70%	30%	
Foothill Sage	-	4	25	34	18	19	21	5	89	126	215
07	-	3%	20%	27%	14%	15%	17%	4%	41%	59%	
Foothill Grassland	1	2	18	16	22	39	12	11	145	121	266
08	1%	2%	15%	13%	18%	32%	10%	9%	55%	45%	
Central Grassland	4	6	104	94	84	124	46	3	571	465	1036
12	1%	1%	22%	20%	18%	27%	10%	-1%	55%	45%	
Ponderosa Pine Savannah	-	1	4	9	10	12	-	1	7	37	44
17	-	4%	11%	24%	27%	32%	-	4%	15%	85%	
Northeastern Grassland	-	2	41	47	65	114	36	1	623	306	929
18	-	-1%	13%	15%	21%	37%	12%	-	67%	33%	
Stream & Lake Bottom	2	-	42	41	33	49	17	5	331	189	520
21	1%	-	22%	22%	17%	26%	9%	3%	64%	36%	
Statewide	23	33	340	318	296	442	169	28	2149	1649	3798
	1%	2%	21%	19%	18%	27%	10%	2%	57%	43%	

steep slopes nonetheless, and add materially to the general problem. A few of the extremely steep slopes were well stabilized by permanent and desirable vegetative cover, and many were partially stabilized on the middle and lower limits, but in general, steep slopes supported a meager cover of annual grasses and weeds, far less than the amount required to materially control erosion. Some peculiarities in the profile shape characteristics of steep slopes were found to be surprisingly important to the successful establishment of cover. All steep but vegetated slopes lacked a sharp angle at the top and usually at the toe. Sharp angular bases of slopes were sometimes encountered, but these were thought to have been created following stabilization by regrading of side borrows, cleaning ditches to maintain drainage, and rebuilding of shoulders. Not a single observation was recorded in which a steep slope with an overhanging turfcap at the top had a satisfactory vegetative cover. Sedimentation originating from beneath the turfcap and aggravated constantly by wind, water and gravitational forces apparently prevented the encroachment of aggressive perennial grasses toward the limits of the banks. These observations point out that at least temporary stabilization of steep seedbeds is a prerequisite to the successful establishment of a permanent vegetative cover. Permanent stabilization might be accomplished in many instances by shaping the upper portions of slopes to eliminate the turfcap effect. By applying protective mulches, temporary stabilization could be gained.

Species Implications - Broad groupings of data indicated the more widely adaptable species and their suitability to particular roadside conditions. Sorting the complex mass of data collected, by considering species location and frequency, those species with the broadest tolerance to a wide variety of growing conditions were determined. It was found that western wheatgrass and Kentucky bluegrass are the most frequent among the desirable species encountered on roadsides throughout the state. However, when the data are limited to slopes only, western wheatgrass is conspicuously lacking. Table 3 shows a comparison of the frequency of the predominant plant species from gently and steep slopes in eastern and western Montana. Deduction indicates that western wheatgrass is an extremely effective performer on the flats and on borrows where soils are of a fine texture, but the species was not frequently found on steep, coarse soils. On the other hand, Kentucky bluegrass appears on slopes throughout the State as the third most frequent perennial grass species. It consistently ranks as the number one perennial grass on slopes in western Montana, but is surpassed by slender wheatgrass and crested wheatgrass in several extensive droughty eastern vegetative zones. The diversity and aggressiveness of Kentucky bluegrass suggests that accessions of it be developed and included in seed mixtures for roadside stabilization purposes in Montana. Graphs and tables of these and other species within vegetative zone are included in this report as Table 4-9 and Figures 3 and 4. These data emphasize the remarkable adaptability of crested wheatgrass to severe situations in both eastern and western Montana, and the outstanding performance and persistence of slender wheatgrass. Both species appear to be effective roadside stabilizers. (These data contradict the general belief that slender wheatgrass is a short-lived species in Montana.)

The rate of establishment of species is a characteristic of importance to erosion control and revegetation work. The data from the survey substantiated earlier observations concerning annual weeds and grasses as being the first to invade and become established on raw soils, either

Table 3. Frequency of single predominant plant species compared on gentle and steep slopes in western and eastern Montana.

	Western Montana (Livingston West) Mountain Area		Eastern Montana (Livingston East) Plains Area	
Gentle Slopes 6:1 through 4:1	#1 Kentucky bluegrass	12.2%	#1 Crested wheatgrass	12.7%
	#2 Slender wheatgrass	10.5	#2 Western wheatgrass	10.8
	#3 Annual bromes	7.0	#3 Firebush	8.2
	#4 Sweetclover	6.4	#4 Annual bromes	7.4
	#5 Crested wheatgrass	6.1	#5 Sweetclover	6.3
		42.2% of 342 samples		45.4% of 379 samples
Steep Slopes 3:1 through 1/2:1	#1 Annual bromes	10.0%	#1 Annual bromes	12.5%
	#2 Bare ground	7.5	#2 Firebush	12.0
	#3 Slender wheatgrass	6.7	#3 Needleandthread	10.0
	#4 Kentucky bluegrass	6.3	#4 Crested wheatgrass	10.0
	#5 Sweetclover	5.3	#5 Slender wheatgrass	7.3
		35.8% of 570 samples		51.8% of 440 samples

Table 4. Primary and secondary species, ranked by frequency, within each vegetative zone.

Vegetative Type	Primary	Secondary
Subalpine Forest	#1 Smooth bromegrass #2 Wild rose #3 Slender wheatgrass #4 Kentucky bluegrass	#1 Smooth bromegrass #2 Big sagebrush #3 Willow
Larch - Douglas Fir	#1 Kentucky bluegrass #2 Timothy #3 Quackgrass #4 Black medic	#1 Kentucky bluegrass #2 Timothy #3 Russian knapweed #4 Strawberry #5 Quackgrass
Lodgepole Pine - Douglas Fir	#1 Cheatgrass #2 Wild rose #3 Smooth bromegrass #4 Timothy	#1 Sweetclover #2 Cheatgrass #3 Timothy
Western Ponderosa Pine	#1 Kentucky bluegrass #2 Russian knapweed #3 Quackgrass #4 Sweetclover	#1 Russian knapweed #2 Cheatgrass #3 Kentucky bluegrass
Intermountain Valley Grassland	#1 Kentucky bluegrass #2 Quackgrass #3 Slender wheatgrass #4 Smooth bromegrass #5 Crested wheatgrass	#1 Kentucky bluegrass #2 Smooth bromegrass #3 Crested wheatgrass #4 Quackgrass #5 Western wheatgrass
Foothill Sagebrush	#1 Cheatgrass #2 Slender wheatgrass #3 Sweetclover #4 Kentucky bluegrass #5 Quackgrass #6 Western wheatgrass	#1 Cheatgrass #2 Slender wheatgrass #3 Sweetclover #4 Crested wheatgrass #5 Western wheatgrass #6 Kentucky bluegrass
Foothill Grassland	#1 Kentucky bluegrass #2 Needleandthread #3 Western wheatgrass #4 Mustard #5 Quackgrass	#1 Slender wheatgrass #2 Kentucky bluegrass #3 Western wheatgrass #4 Needleandthread
Central Grassland	#1 Western wheatgrass #2 Crested wheatgrass #3 Firebush #4 Cheatgrass #5 Slender wheatgrass #6 Needleandthread	#1 Cheatgrass #2 Crested wheatgrass #3 Western wheatgrass #4 Slender wheatgrass #5 Firebush

Continued on next page.

Table 4. Continued.

Vegetative Type	Primary	Secondary
Ponderosa Pine Savannah	#1 Cheatgrass #2 Mustard #3 Chokecherry #4 Fringed sagewort	#1 Sweetclover #2 Cheatgrass
Northeastern Grassland	#1 Crested wheatgrass #2 Western wheatgrass #3 Slender wheatgrass #4 Smooth bromegrass #5 Needleandthread	#1 Crested wheatgrass #2 Slender wheatgrass #3 Needleandthread #4 Western wheatgrass #5 Sweetclover
Stream and Lake Bottoms	#1 Kentucky bluegrass #2 Smooth bromegrass #3 Western wheatgrass #4 Cheatgrass #5 Crested wheatgrass	#1 Cheatgrass #2 Kentucky bluegrass #3 Crested wheatgrass #4 Green needlegrass #5 Western wheatgrass

Table 5. Frequency ratios of most common primary species on several gradients as affected by directional exposures within the Northeastern Grassland zone.

Species	Gradients	Exposure N	Exposure E	Exposure S	Exposure W
Kentucky bluegrass	3:1	1	-	1	2
Needleandthread	3:1	2	3	-	1
Green needlegrass	3:1	-	1	1	1
Crested wheatgrass	3:1	5	10	10	4
Slender wheatgrass	3:1	5	2	3	-
Firebush	3:1	1	2	4	1
Mustard	3:1	1	2	2	1
Sweetclover	3:1	3	2	2	3
Foxtail barley	2:1	1	-	1	1
Needleandthread	2:1	2	7	13	4
Crested Wheatgrass	2:1	1	7	2	1
Slender wheatgrass	2:1	2	2	4	4
Needleandthread	1:1	1	5	6	1
Crested wheatgrass	1:1	3	4	2	2
Slender wheatgrass	1:1	3	-	1	2
Sweetclover	1:1	3	2	-	2

Table 6. Primary and secondary species, ranked by frequency as influenced by exposure within Central Grassland vegetative zone.

Vegetative Type	Primary	Secondary
Level	#1 Western wheatgrass	#1 Western wheatgrass
	#2 Kentucky bluegrass	#2 Crested wheatgrass
	#3 Crested wheatgrass	#3 Kentucky bluegrass
	#4 Slender wheatgrass	#4 Smooth bromegrass
	#5 Smooth bromegrass	#5 Slender wheatgrass
North	#1 Sweetclover	#1 Russian thistle
	#2 Slender wheatgrass	#2 Crested wheatgrass
	#3 Firebush	#3 Slender wheatgrass
	#4 Needleandthread	#4 Firebush
	#5 Quackgrass	#5 Snakeweed
Northeast	#1 Cheatgrass	#1 Broom snakeweed
	#2 Crested wheatgrass	#2 Cheatgrass
	#3 Slender wheatgrass	#3 Slender wheatgrass
	#4 Wild lettuce	#4 Green needlegrass
	#5 Sweetclover	#5 Alfalfa
East	#1 Firebush	#1 Wild lettuce
	#2 Broom snakeweed	#2 Russian thistle
	#3 Crested wheatgrass	#3 Broom snakeweed
	#4 Needleandthread	#4 Slender wheatgrass
	#5 Slender wheatgrass	#5 Firebush
Southeast	#1 Cheatgrass	#1 Firebush
	#2 Firebush	#2 Cheatgrass
	#3 Crested wheatgrass	#3 Broom snakeweed
	#4 Russian thistle	#4 Silver sagebrush
	#5 Needleandthread	#5 Indian ricegrass
South	#1 Firebush	#1 Cheatgrass
	#2 Green needlegrass	#2 Firebush
	#3 Cheatgrass	#3 Russian thistle
	#4 Slender wheatgrass	#4 Broom snakeweed
	#5 Western wheatgrass	#5 Needleandthread
Southwest	#1 Crested wheatgrass	#1 Crested wheatgrass
	#2 Cheatgrass	#2 Cheatgrass
	#3 Russian thistle	#3 Slender wheatgrass
	#4 Western wheatgrass	#4 Sweetclover
	#5 Firebush	#5 Silver sagebrush
West	#1 Firebush	#1 Russian thistle
	#2 Needleandthread	#2 Firebush
	#3 Western wheatgrass	#3 Cheatgrass
	#4 Silver sagebrush	#4 Sweetclover
	#5 Russian thistle	#5 Gumweed
Northwest	#1 Firebush	#1 Russian thistle
	#2 Slender wheatgrass	#2 Cheatgrass
	#3 Needleandthread	#3 Kentucky bluegrass
	#4 Silver sagebrush	#4 Wild lettuce
	#5 Smooth bromegrass	#5 Sweetclover

Table 7. Frequency of several common species of vegetation on roadsides as affected by exposure for Central Grassland zone.

Species	Slopes	Exposure			
		N	E	S	W
	Less than 3:1 (278 Samples)	(61)	(86)	(64)	(67)
Foxtail barley		4	5	1	1
Kentucky bluegrass		2	4	1	
Smooth bromegrass		2	1	2	4
Cheatgrass		9	15	5	3
Needleandthread		2	3	3	8
Green needlegrass		1	1	5	2
Crested wheatgrass		5	7	10	10
Slender wheatgrass		7	5	5	5
Quackgrass		1	1		
Alfalfa					
Western wheatgrass		3	3	7	2
Sand dropseed		1	2	1	
Kochia		3	12	5	7
Mustard					
Russian thistle		2	4	8	4
Sweetclover		8	9	4	3
Wild lettuce		4	4	1	1
Broom snakeweed		1	1	2	2
Rabbitbrush			1	2	1
Fringed sagewort				1	
Silver sagebrush					1
	3:1 and steeper (469 Samples)	(123)	(139)	(101)	(106)
Foxtail barley		3	3	1	2
Kentucky bluegrass			1		
Cheatgrass		20	24	19	13
Needleandthread		4	4	4	5
Green needlegrass		3	3	4	5
Indian ricegrass		3	5	2	4
Crested wheatgrass		8	11	8	8
Slender wheatgrass		11	12	6	6
Quackgrass		2	1	2	1
Western wheatgrass		4	5	33	3
Alfalfa		1	1	1	1
Kochia		12	19	18	22
Mustard		5	5	1	1
Russian thistle		4	4	7	10
Sweetclover		7	2	6	9
Wild lettuce		5	5	2	2
Broom snakeweed		8	9	1	2
Rabbitbrush		1	1		
Silver sagebrush		2	1	2	3
Fringed sagewort		5	5	1	

Table 8. Frequency of several common species of vegetation on roadsides as affected by exposure for Northeastern Grassland zone.

		Exposure			
Species	Slopes	N	E	S	W
	Less than 3:1 (234 Samples)	(40)	(67)	(89)	(38)
Foxtail barley			1	8	1
Kentucky bluegrass		2		1	1
Smooth bromegrass		8	9	14	6
Cheatgrass				1	
Needleandthread			4	3	
Green needlegrass		2	4	2	
Crested wheatgrass		7	25	27	15
Slender wheatgrass		6	8	19	9
Quackgrass		1	6	9	1
Western wheatgrass		5	9	13	5
Firebush		9	9	6	2
Mustard		1			
Russian thistle		4	4	4	4
Sweetclover		3	6	9	4
Wild lettuce		1	2	1	
Fringed sagewort				1	1
	3:1 and steeper (232 Samples)	(54)	(64)	(76)	(38)
Foxtail barley		1	1	2	1
Kentucky bluegrass		1		1	2
Smooth bromegrass		3	2	3	1
Cheatgrass		1	1		
Needleandthread		5	15	19	6
Green needlegrass			1	1	1
Crested wheatgrass		9	21	14	7
Slender wheatgrass		10	4	9	16
Quackgrass		2		1	
Western wheatgrass		3		1	1
Firebush		2	3	5	1
Mustard		1	3	5	2
Sweetclover		6	4	3	5
Wild rose		1			1
Big sagebrush			1	1	

Table 9. Frequency of several common species of vegetation on roadsides as affected by exposure for Stream and Lake Bottom zone.

		Exposure			
Species	Slopes	N	E	S	W
	Less than 3:1 (104 Samples)	(33)	(22)	(23)	(26)
Foxtail barley		1			1
Kentucky bluegrass		4		1	3
Smooth bromegrass		2	2		1
Cheatgrass		2	2	8	7
Needleandthread					
Green needlegrass		1			
Timothy		1			
Crested wheatgrass		6	9	4	6
Slender wheatgrass		5	2		3
Quackgrass		1			
Western wheatgrass		1	1	4	1
Firebush		2		2	1
Russian knapweed		1		2	
Sweetclover		2			2
	3:1 and steeper (168 Samples)	(44)	(33)	(55)	(36)
Foxtail barley					
Kentucky bluegrass		4	2		1
Smooth bromegrass		3	1	2	2
Cheatgrass		5	2	14	11
Needleandthread		1	3	4	
Green needlegrass		1			
Timothy					
Crested wheatgrass			4	2	2
Slender wheatgrass		4	1	3	2
Quackgrass		1	2		1
Western wheatgrass				1	
Firebush		1			
Russian knapweed		2	2	3	1
Wild lettuce		1	1	2	1
Sweetclover		3	4	7	2
Wild rose		1	1		
Willow		3	3		

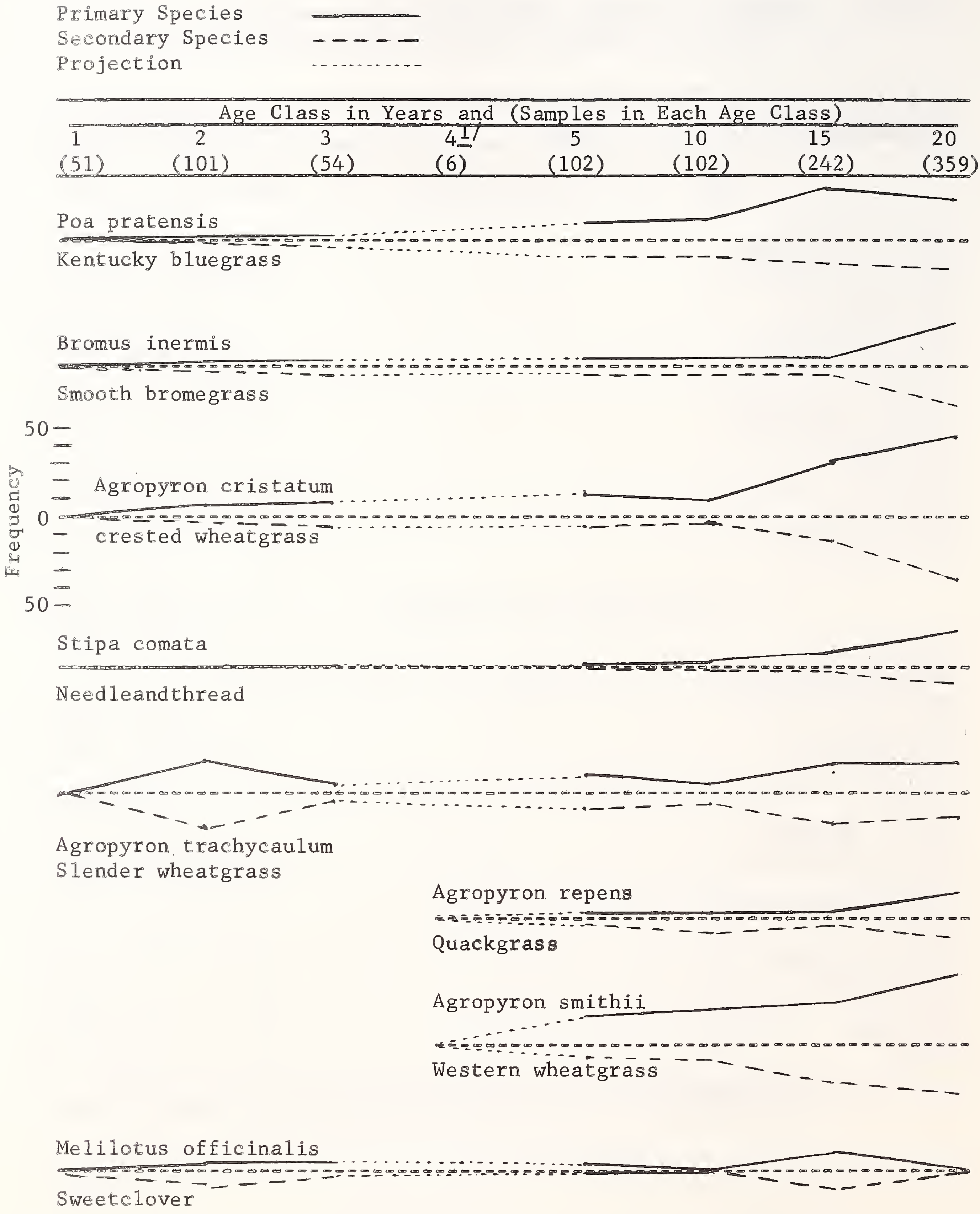

Figure 3. Incidence of primary and secondary species on roadsides of various age classes, Central Grassland (1032 samples).

1/ Four year age class has too few samples for adequate representation and is projected on graphs.

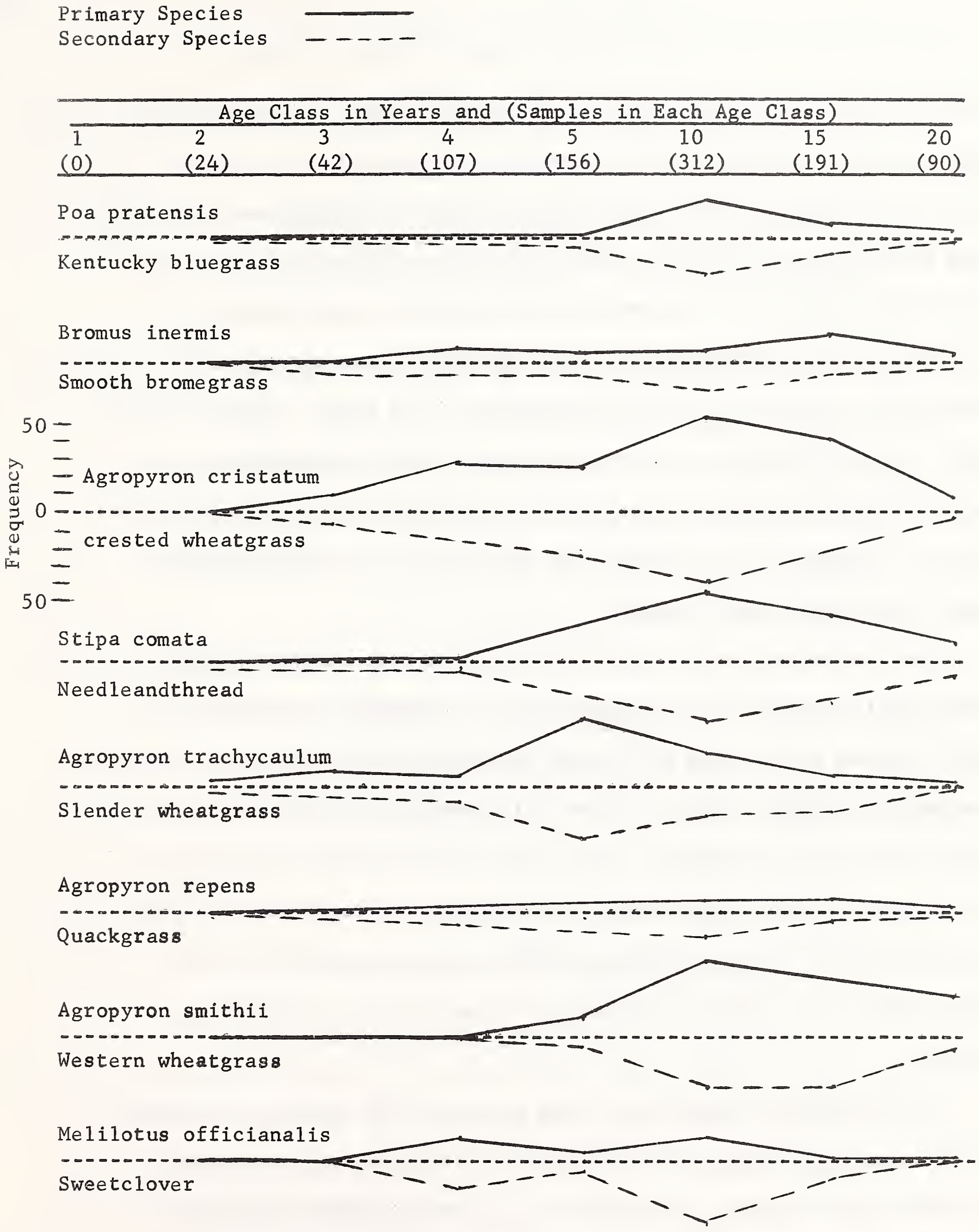

Figure 4. Incidence of primary and secondary species on highway sideborrows of various age classes, Northeastern Grassland (922 samples).

sloping or flat. This study showed the annual bromes (cheatgrass and Japanese brome), firebush, Russian thistle and sweetclover to be the usual early natural invaders on roadside slopes. Although some perennial grass seedlings may naturally invade a dry site within two seasons, the data indicate that four or more years are usually required before any substantial amounts of desirable cover may appear, and closer to 15 years may be required in the drier portions of the state. Kentucky bluegrass, slender wheatgrass, crested wheatgrass, and needleandthread are among the "early comers". This lag in the natural invasion and establishment of a suitable cover stresses the importance of reseeding highway slopes immediately after grading.

The data accumulated in this study were directly influenced and restricted by factors of the adjacent area. Certainly no species can readily invade a bare area and become established there in quantity without a nearby and adequate source of seed. It should not, however, be construed that merely providing a seed source of an existing species can in any sense replace experimental investigations to find other species more effective for reseeding purposes than those encountered in the survey, which are largely the result of invasion on old roadsides in Montana.

The influences of specific site factors (such as slope, exposure, or moisture) were found to be indistinct or inconsistent even within apparently similar sites and conditions. Some consistencies appeared among various combinations of growth factors. However, by studying the frequency of the established primary and secondary species of vegetation among various combinations, and within the established vegetative type zones throughout the state, pertinent and applicable information was derived.

Job #2. CONTRACT SEEDING EVALUATION

INTRODUCTION - A second survey begun during the first field season of the highway revegetation research project involved an extensive evaluation of previous contract seeding attempts for the purpose of determining the effectiveness of seeding practices and special provisions included in seeding contracts.

PROCEDURE - Data from all available sources were accumulated on all contract roadside seedings which had been conducted in Montana between 1960, the date of the first contract seeding, and 1964, the commencement date of the research study. Major sources of information were: Montana Highway Department files; interviews with individuals who observed the seeding job, its development and maintenance; and on-the-site inspections and evaluations.

Information obtained from the five seedings which were made in 1960 was considered inadequate. No contract seedings were made in 1961, seven were made in 1962 and 12 were accomplished in 1963. These seeding locations were widely spread and growing conditions were dissimilar. Many discrepancies and inconsistencies were found and conflicting entries from the several sources of information confounded these data and in some cases made interpretation difficult or meaningless. Consequently, in order to accumulate sufficient meaningful data about seeding response and development, this study was continued through several more consecutive seasons. Observations and evaluations of all ages of contract seeded areas were made during the growing seasons of 1964 through 1967. This extended time period allowed the collection of data from 42 locations where information was acquired over at least two consecutive years. The questionnaire format used consistently each year in evaluating each seeding appears in Figure 5. Examiners were trained each season in the use of the questionnaire to produce a consistent quality of data acquisition.

The Chi-square test contingency analysis was used to examine the accumulated data pertaining to seeding success as affected by variables such as time of seeding, exposure, gradient or soil amendment.

RESULTS AND RECOMMENDATIONS - Analysis of the data from these sites demonstrated the one most consistent characteristic to be extreme variability - in species used, in time of planting, in soil conditions, in weather conditions, in special provisions, in seeding practices and in equipment used. In no case were results obtained by any one particular seeding practice significantly better on a similar exposure or slope. These results are contrary to the findings of research plantings at various locations within the State where, for example, time of seeding has been shown to be critical.

Table 10 shows percentages of contract seedings considered successful or unsuccessful as a function of slope and time of seeding. Ratings were consistently higher for spring seedings in the steep slope category. The fill slope category also suggests some advantage to spring seeding.

It is concluded from this endeavor that extreme variance and lack of consistency of the many contract seeding characteristics noted warrant more carefully executed seeding procedures, specifications and data recording if consistently successful seeding results are to be obtained.

Individual seedings cannot be evaluated comparatively without these data because there were too many influential factors not recorded and therefore unknown - condition of seedbed, machinery used, depth of seed placement, weed competition, weather conditions, etc.

Figure 5: Highway Contracted Seeding Evaluation

Examiner: Date: Writeup No.:

Route No.: Station No.: Contract No.:

Study Control No.:

PHYSIOGRAPHY
Character - Cut, Fill, Side Borrow
Elevation - 0-1000-2000-3000-4000-5000-6000-7000
Inslope:
  Exposure - N-E-S-W
  Length - 5-20-35-50-65
  Gradient - 6:1, 5:1, 4:1, 3:1, 2:1, 1:1
  Cover - Adequate, inadequate, none
Backslope:
  Exposure - N-E-S-W
  Length - 5-20-35-50-65-80-95-110-125
  Gradient - 4:1, 3:1, 2:1, 1:1, 3/4:1, 1/2:1, 1/4:1
  Cover - Adequate, inadequate, none

SOIL CHARACTERISTICS
Series:
Class - Sandy, Silty, Loamy, Clayey, Gravelly, Rocky, Outcrops, Mixture, Banded.
Depth A & B - 0-3-6-9-12-15-18-24
Moisture - Dry temp., Dry per., Wet temp., Wet perm., Subirrigated, Overflow, Seep
Erosion - Sheet, Rill, Gulley, Wind, Slide, Flow, Rain, Overflow, Int. Stream, Seep, Spring, Slight, Moderate, Severe, Measurement of erosion.
Soil Analysis: Mech. analysis, Free salt status, Sodium pH, N & P
  Type of clay - Swelling potential, Erosion potential

WEATHER DATA: Temp., ppt., wind

REVEGETATION DATA
Seeding - Year and Season
  Species, variety, source, germ., purity
Practices - seedbed prep.: none, cult, amended, packed
  Seeding techniques - Broadcast, Drilled, Hydroseeder
  Fertilizers
  Innoculants
  Mulches
  Mechanical protection

VEGETATIVE STUDIES
Seedlings/sq. ft., 1^o slope
Recon. density
Photographic techniques, general specific
Rectangular Grid Quadrat

Table 10. Seeding success (Spring -vs- Fall). Seeding by slope category and age class.

No. of Growing Seasons	STEEP SLOPES		Total Evalua-tions	FLAT AREAS		Total Evalua-tions	NORTHEAST SLOPE		Total Evalua-tions	SOUTHWEST SLOPE		Total Evalua-tions	FILL SLOPES		Total Evalua-tions
	SPRING	FALL		SPRING	FALL		SPRING	FALL		SPRING	FALL		SPRING	FALL	
1	62% (8/13)*	50% (2/4)	17	94% (16/17)	100% (8/8)	25	83% (5/6)	100% (3/3)	9	33% (2/6)	66% (2/3)	9	94% (15/16)	83% (5/6)	22
2	47% (7/15)	38% (3/8)	23	100% (17/17)	92% (11/12)	29	88% (12/14)	60% (3/5)	19	53% (8/15)	40% (2/5)	20	73% (11/15)	66% (6/9)	24
3	46% (6/13)	20% (1/5)	18	100% (17/17)	100% (7/7)	24	94% (15/16)	85% (6/7)	23	40% (4/10)	57% (4/7)	17	60% (9/15)	50% (2/4)	19
4	50% (2/4)	33% (3/9)	13	100% (8/8)	100% (9/9)	17	50% (2/4)	71% (5/7)	11	50% (2/4)	71% (5/7)	11	80% (4/5)	85% (6/7)	12

* (8/13) = 8 out of 13 is 62%.

Perhaps the greatest value of this extensive effort is in emphasizing the need for qualified and trained personnel in the supervision of roadside seeding processes from road planning specifications through the execution of the planting procedures. Certainly if full benefit is derived from past successes and failures, a methodical recording system of seeding characteristics is essential, and this is possible to accomplish only with personnel trained to acquire and analyze the data. The importance of this work to insure greater success in the future cannot be overemphasized.

Job #3. SEED GERMINATION STUDY

INTRODUCTION - Interpretations from the two roadside surveys which began in 1964 suggested the need for a seed germination study to provide essential information on particular characteristics of available forage species currently being used, and also on native species thought to be better adapted to the existing soil conditions, possibly eliminating the need for soil amendments including topsoiling or other special provisions. Germination characteristics and seedling development data of many native grasses, as well as broadleafed plants, were not previously available. Such characteristics greatly influence the success of seedling establishment on semiarid slopes; success is enhanced by the use of species that germinate rapidly, produce substantial root development prior to shoot growth and are adapted to the site at maturity. These characteristics are obtained by species selection.

Also, the effects of fertilizer on grass seeds, especially when applied with a hydroseeder, were unknown for most species. The hydroseeding process offers many new opportunities and challenges in roadside seeding even where other planting techniques might be more successful. It allows the use of materials and seeds previously considered difficult or impractical to utilize. It makes possible the seeding, fertilizing, and mulching of inaccessible slopes in an economical one-pass operation. However, there are few studies pertaining to the effects of fertilizer slurries of the hydroseeding process on seed viability and germination.

In the hydroseeding process, seed is soaked, violently agitated and recirculated under pressure in direct contact with varied concentrations of fertilizers contained in the slurry mixture. It was felt that such techniques as using fertilizer slurries may alter species traits by reducing seed germination and detrimentally modifying seedling development to a critical extent. Consequently, studies were initiated to determine the effects of a hydroseeder fertilizer slurry, both simulated and actual, on seed germination.

PROCEDURES - Three studies were conducted to determine the effects of hydroseeding with fertilizer slurries on germinating seeds. The first study tested seed germination in the presence of NH_4NO_3 fertilizer. The second involved fertilizer, pressure and agitation. The third tested germination of retrieved seeds which had gone through the hydroseeding process.

Study I: In the initial laboratory fertilizer study, data were obtained from standard germination blotter tests of 21 days duration with 100 seeds to each blotter, protected and kept continuously damp in covered plastic petri dishes. Tests were conducted either at room temperature (approximately 65 - 80 degrees F) or in germinators simulating springtime conditions (35 - 75 degrees with 12 hours of daylight). There were three replicates in each test. There were 2,297 tests of 161 species, lots and selections for germination. Seedling development data were obtained from the last 477 of these tests.

The treatments were designed to simulate field application rates of 0, 30 and 60 pounds of nitrogen per acre. The concentrations of solutions used were based on the weight of water in the top acre-inch of a typical roadside backslope assuming 15% moisture content. Treatments included distilled water, or .022 N ammonium nitrate, or .044 N ammonium nitrate, respectively. A quantity of 25cc was sufficient to initially dampen the germination pads. Daily inspection and watering with distilled water to original dampness maintained humidity and approximate concentration of treatment throughout each test period. The effect of nitrogen upon root and shoot development was evaluated by comparing seedling development in water and in the nitrogen solutions. Shoot and root development was classified visually into four categories: (1) none, (2) poor, (3) good and (4) excellent. Inconsistencies were common within trials making ranking by species difficult. Some species were tested many times, depending on personal interest and on importance to the roadside seeding program, others were tested as few as three times.

Study II: The second study was designed to determine individual, as well as combined, effects of fertilizer, pressure, and agitation on three selected grass species - slender wheatgrass, crested wheatgrass, and meadow fescue.

Seeds were treated in a high pressure cylindrical canister at 100 psi. Agitation was provided by a conventional commercial paint shaker.

Following a treatment duration period of 15 minutes, seeds were removed from the canister and thoroughly rinsed in distilled water, drained, counted, and placed on clean blotters in petri dishes for testing. Germination data were recorded as in the first study.

Study III: For the third study, a hydroseeder slurry was made consisting of one pound each of nine species in 100 gallons of water to which 100 pounds of 23-23-0 fertilizer were added. This slurry simulated a seeding rate of 18 pounds per acre and a fertilizing rate of 200 pounds per acre. This mixture was circulated in the hydroseeder for 30 minutes. The circulating pump provided a psi of 100 plus.

A composite seed sample was retrieved from the hydroseeder by straining a portion of the slurry from the hydroseeder drain through a burlap sack while the machine was operating. This sample was then washed thoroughly, dried, sorted by species, and counted into samples of 100 seeds each for testing as previously described. Data from this germination study came from 519 tests of 100 seeds each. Germination tests were extended from the standard 21 days to 30 days in order to obtain more complete data on the slower germinating species such as western wheatgrass.

Control tests for each species from identical lots were run concurrently with the treated seed tests. The nine species tested were: tall wheatgrass, slender wheatgrass, Lincoln bromegrass, prairie sand reed, Canada wildrye, Canada bluegrass, sand dropseed, fourwing saltbrush and white-flowered prairie clover.

Mechanical damage to seeds caused by the hydroseeder was determined by sorting random 10 gram samples of treated seed into damaged and undamaged lots by species, excepting the two wheatgrasses which were grouped. Untreated seed lots sorted into damaged and undamaged component parts served as controls. A considerable portion of the material recovered from the hydroseeder slurry was unidentifiable. Consequently, data on mechanical damage are based only on identifiable material and thus do not reflect total damage caused by the hydroseeder.

RESULTS AND RECOMMENDATIONS -

Study I: Based on the average of all species and trials included in the first study, the .022 solution increased total germination while the .044 rate resulted in a slight decrease. The average total germination percentages for all species were 36, 43, and 34 percent for distilled water, for .022 N and for .044 N silutions, respectively. Although germination was increased at the .022 N level, root and shoot development were often adversely affected. The fertilizer treatment tended to retard or inhibit growth in the new roots and shoots of some species. Table 11 lists 37 species grouped by performance and reaction of roots to the same fertilizer treatment.

Study II: An analysis of the accumulated data from the second study on the effect of agitation, fertilizer and pressure showed some definite trends (Table 12). The most obvious observation was that the lowest germination was obtained with the agitation--pressure--fertilizer combination treatment and the highest germination was with agitation and pressure only. Seed germination under the agitation--pressure treatment was significantly better and surpassed the controls in all species except in one lot of slender wheatgrass which appeared better but not significantly so.

Two species, meadow fescue and Lot #362 of slender wheatgrass, were not significantly affected by any treatments except the agitation--pressure--fertilizer combination which again produced the least germination. Crested wheatgrass and Lot #452 of slender wheatgrass proved quite sensitive to treatment variations. They averaged, respectively, 45 and 51 percent less germination with the agitation--pressure--fertilizer treatment than with agitation--pressure alone.

Table 11. Root development response of germinating seeds to ammonium nitrate by species.

Negative Response (Detrimental)	Positive Response (Beneficial)	Inconsistent Response
Crested wheatgrass	Pigweed	Western wheatgrass
Thickspike wheatgrass	Buffalograss	Bluebunch wheatgrass
Tall wheatgrass		Canada wildrye
Siberian wheatgrass		Meadow barley
Little bluestem		Canada bluegrass
Red threeawn		
Field sagewort		
Green sagewort		
Fringed sagewort		
Blue grama		
Japanese brome		
Hairy goldenaster		
Western white clematis		
Inland saltgrass		
Winterfat		
Hard fescue		
Red fescue		
Sixweeks fescue		
Curlycup gumweed		
Broom snakeweed		
Foxtail barley		
Firebush		
Black medic		
Alfalfa		
Sweetclover		
Plains pricklypear		
Green bristlegrass		
Tumblegrass		
Needleandthread		
Bulbous bluegrass		

Table 12. Effects of seed treatment on percent germination.

Seed Treatments1/	Response by Species Meadow Fescue Lot #418	Crested Wheatgrass Lot #356	Slender Wheatgrass Lot #362	Slender Wheatgrass Lot #453
Water in germinator	83.66 ab2/	67.66 a	92.66 a	--3/
Water in room	87.33 a	69.66 a	95.66 a	--
Agitation in room	--	--	94.66 a	--
Agitation and fertilizer in germinator	85.22 ab	66.66 ab	84.77 a	53.33 d
Agitation and fertilizer in room	86.55 ab	60.00 bc	89.33 a	74.33 a
Agitation and pressure in germinator	83.00 ab	75.00 a	--	45.16 e
Agitation and pressure in room	89.66 a	96.66 a	94.00 a	76.83 a
Fertilizer and pressure in germinator	82.33 ab	41.66 e	63.33 b	41.33 e
Fertilizer and pressure in room	84.33 ab	46.66 de	78.00 ab	69.00 b
Agitation, fertilizer, pressure in germinator	79.33 b	53.00 cd	91.00 a	38.00 e
Agitation, fertilizer, pressure in room	82.33 ab	55.66 c	81.33 ab	60.66 c

1/ Arranged in order of increasing severity.

2/ Means within species with one or more letters in common are not significantly different at the 95% confidence level (Duncan, 1955).

3/ Tests not run; data not available.

Study III: The germination test results of the third study were analyzed by the least squares analysis to determine the effect of the hydroseeder on seed germination; and also to determine if seed germination in germinators was significantly different than germination under uncontrolled conditions (Table 13).

The hydroseeder treatment decreased germination in all but two species: sand dropseed germination was significantly increased by the effects of the hydroseeder treatments; Canada bluegrass showed no significant response.

Germination difference, inside or outside the growth chanber, was found to be highly significant in the cases of prairie sand-reed, Canada wildrye, white prairie clover, and sand dropseed. Germination was increased outside the germinator in all four cases.

Mechanical damage was determined only for species with identifiable parts from a specific sample recognized as: Canada wildrye, prairie sandreed and the two indistinguishable wheatgrasses grouped. Materials from other species were not identifiable. Results of this attempt at determining the extent of mechanical damage are presented in Table 14.

Figures 6, 7, 8, and 9 show the effect of the hydroseeder treatment on root and shoot growth. Germination of seed recovered from the hydroseeder was frequently severely retarded.

The data obtained from these experiments indicated that hydroseeding with a fertilizer slurry significantly affects the germination of seeds and seedling development.

Germination of seeds circulated in a hydroseeder fertilizer slurry was decreased significantly in seven of none species tested. These species were tall wheatgrass, slender wheatgrass, fourwing saltbush,

Table 13. Average germination percentages for nine species; inside and outside germinator, hydroseeder treated and control[1/].

Species	Percent Germination				Statistical Significance		
	Inside Germinator		Outside Germinator				
	Hydro-seeder slurry treated	Water control	Hydro-seeder slurry treated	Water control	Inside or outside germinator	Hydro-seeder treated	Inter-action
Tall wheatgrass	46.93	80.33	45.78	77.33		**	
Slender wheatgrass	46.33	95.33	48.17	95.67		**	
Fourwing saltbush	2.04	4.44	1.06	5.17		**	
Lincoln bromegrass	56.55	82.23	62.56	73.50		**	
Prairie sand reed	0.23	69.67	0.44	76.67	**	**	**
Canada wildrye	11.83	28.17	34.33	75.67	**	**	**
White flowered prairie clover	3.06	55.17	4.74	63.11	**	**	*
Canada bluegrass	77.56	87.00	80.61	80.33			
Sand dropseed	25.96	8.44	31.85	14.00	**	**	

[1/] Analysis by least-squares method according to Harvey, 1960.
* $P<0.05$
** $P<0.01$

Table 14. Analysis of the difference of paired samples using student's T test for significance of mechanical damage caused by the hydroseeder[1].

Species	T Value	Significance
Canada wildrye	32.43	**
Prairie sand reed	10.96	**
Tall and slender wheatgrass	6.28	*
White flowered prairie clover	2.43	
Lincoln bromegrass	1.93	

[1] Snedecor, 1956
** Significant at the 0.01 level
* Significant at the 0.05 level

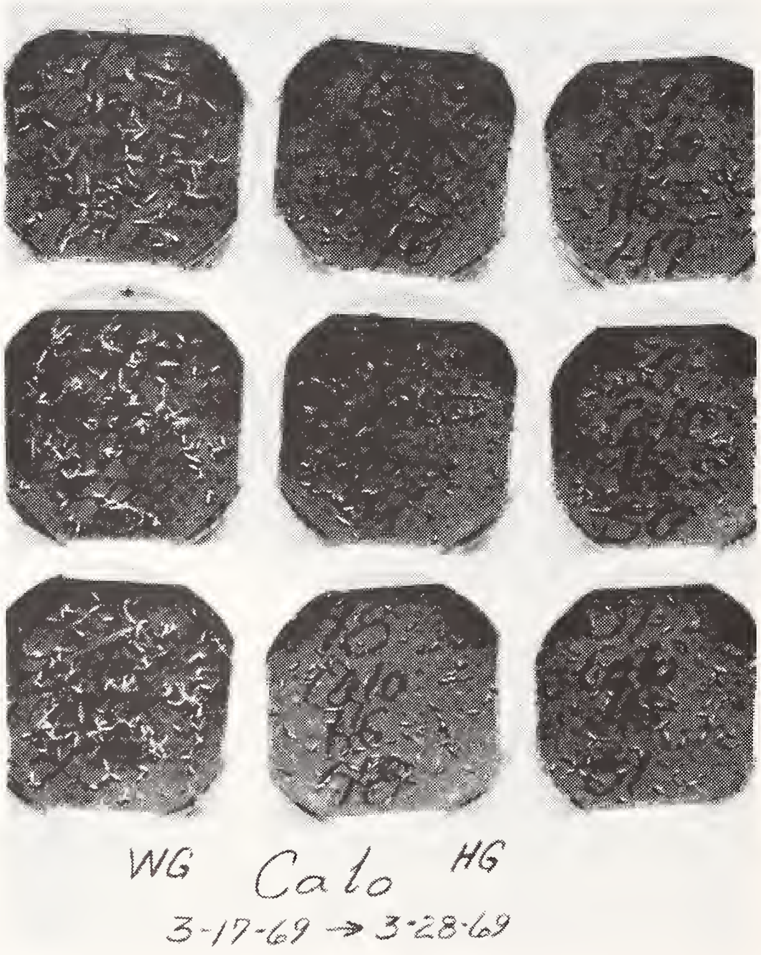

Figure 6 . Prairie sandreed seeds after 11 days in the germinator showing differences in germination between control (WG) and the hydroseeder treatment (HG).

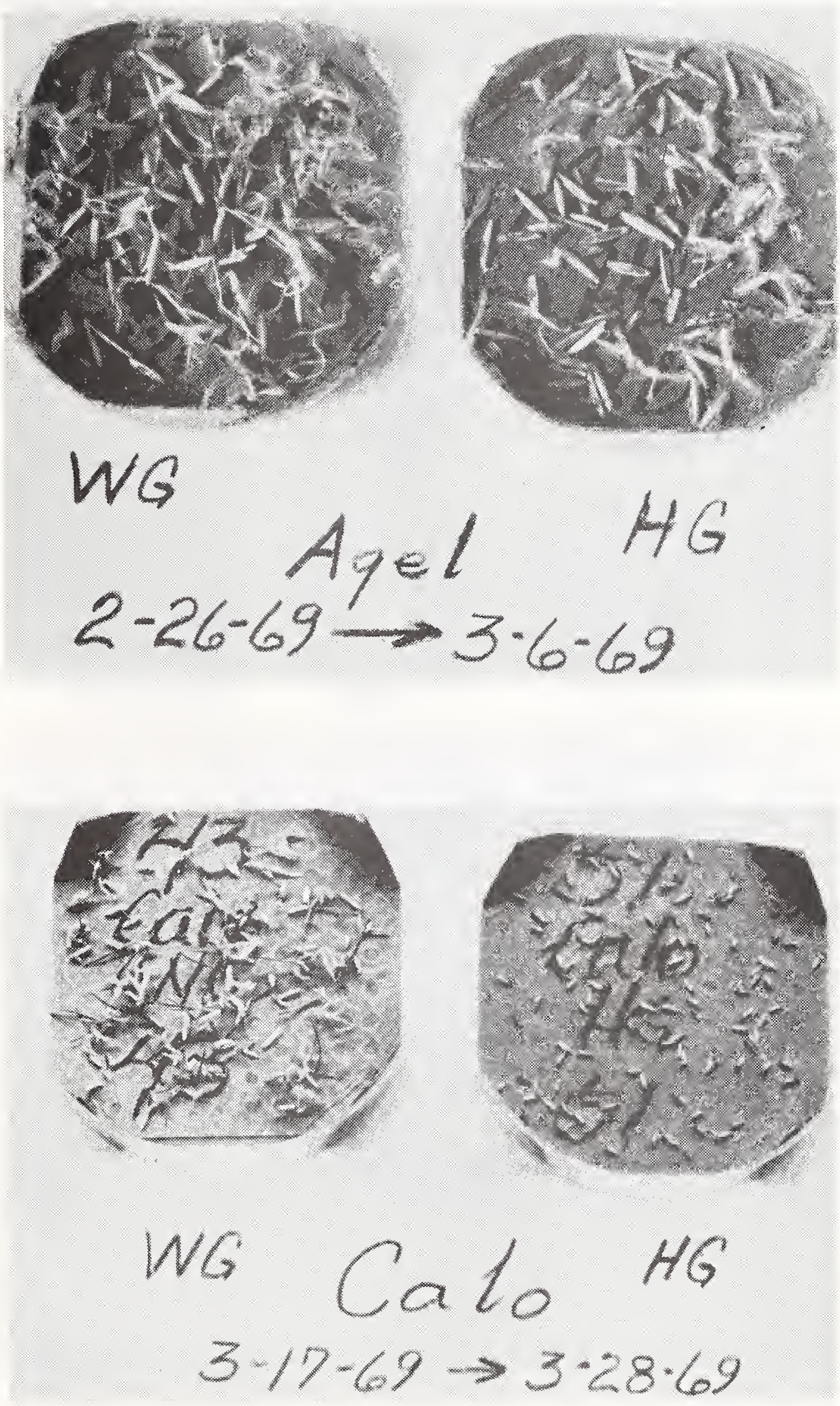

Figure 7 . Close-ups of tall wheatgrass (top) and prairie sandreed (bottom) showing differences in numbers of seed germinated in the control inside germinator (WG) versus hydroseeder treated seed inside germinator (HG).

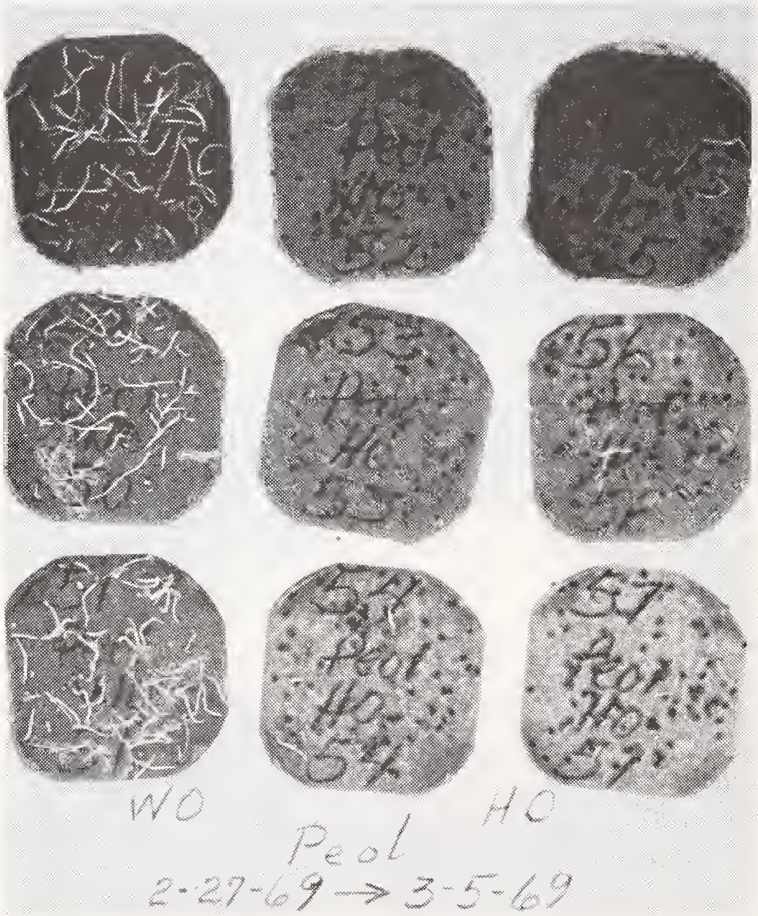

Figure 8 . White-flowered prairie clover after 6 days outside germinator showing differences in germination between control (WO) and the hydroseeder treatment (HO).

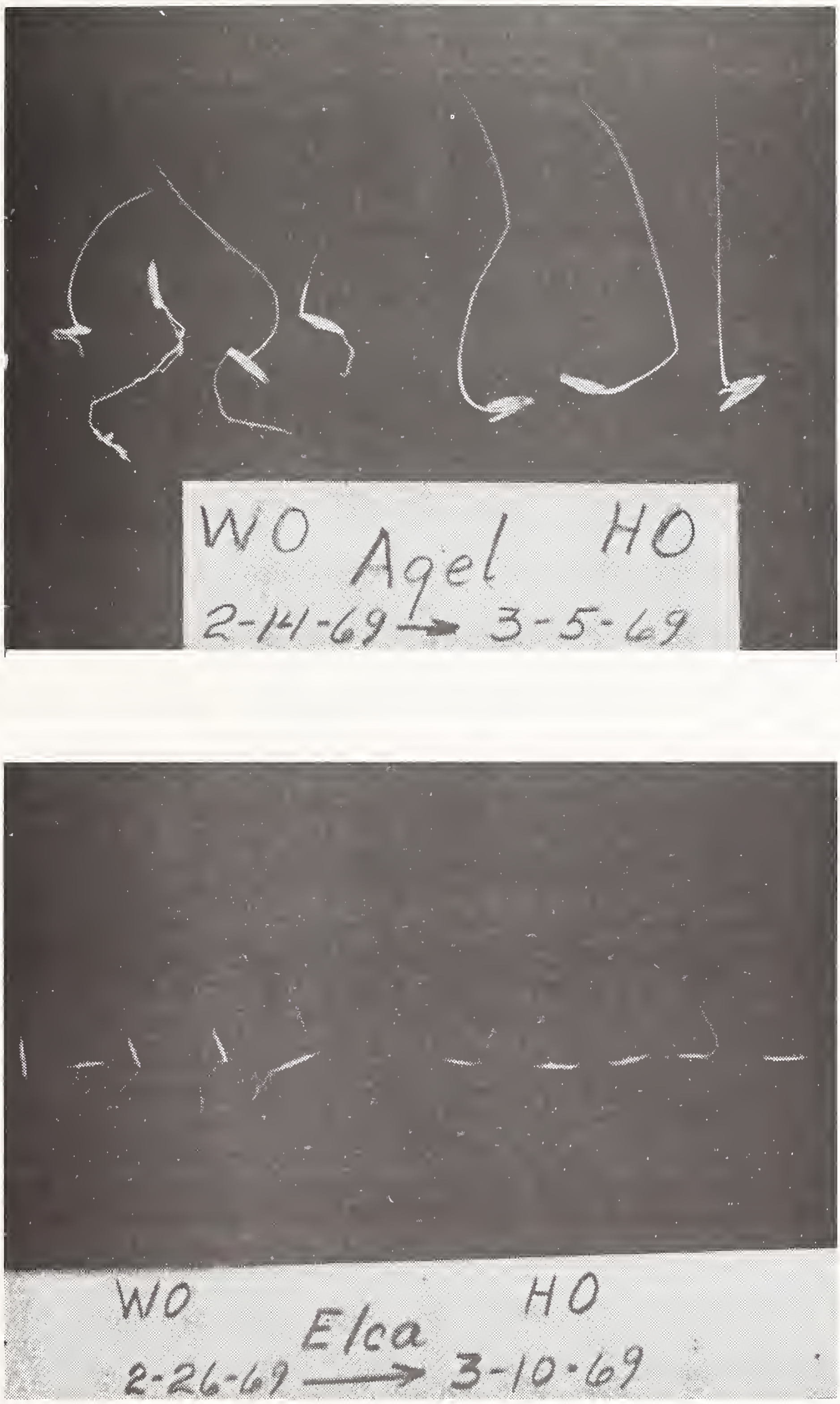

Figure 9 . Differences in root and shoot development of tall wheatgrass (top) after 19 days were apparent between the control (WO) and the hydroseeder treatment (HO). Differences were also apparent in Canada wildrye after 12 days (bottom).

Lincoln brome, prairie sandreedgrass, Canada wildrye and white prairie clover. Germination of sand dropseed was significantly increased. Canada bluegrass was not affected.

Mechanical damage to seeds caused by the hydroseeder is of importance generally in species with large seeds or seeds with loose lemmas and paleas.

It is concluded that hydroseeding with fertilizer slurries under semiarid growing conditions is a questionable practice. It is recommended that hydroseeding and hydrofertilizing be separate operations with hydrofertilizing delayed to follow seedling emergence. When seeding with a hydroseeder is carried out seeding rates should be adjusted to compensate for the reduction in germination and seed viability which occurs as a result of that technique.

Job #4. SOIL TEMPERATURE AND SOIL MOISTURE RELATIONSHIPS

INTRODUCTION - Inconsistencies in the results of the roadside vegetation and contract seeding evaluation surveys of 1965 emphasized the need for acquiring soil moisture and temperature data as affected by exposure and surface treatment to determine if soil moisture was a major contributing factor to discrepancies in recorded seeding results. A study was designed at the Townsend research area for the primary purpose of comparing soil temperature and percent moisture as affected by surface treatments. A secondary purpose of this study was to develop a seeding technique that would make late seeding more practical.

PROCEDURES - Several locations at the Townsend research site were delineated which had north and south exposures including both cuts and fills. Surface treatments were applied in triplicate and consisted of straw and asphalt, Encap (a black agricultural asphalt resin mulch), pitting with a garden hoe, and bare ground. Thermistors were placed barely below the soil surface in each replicate of treatments to measure soil surface temperatures. These were read at the same hour at weekly intervals from June through October for two successive years, 1965 and 1966.

Soil moisture samples from each treated plot were collected each week at inch intervals - surface to 1" deep, 1" to 2" deep, etc., until moist soil was obtained. Soil temperature data were correlated to air temperatures and to weather conditions at the time of reading. Both wind and cloud cover readings were included. Daily precipitation and temperatures were recorded at a permanent weather station maintained in Townsend several miles from the research study site. The ten year average precipitation at this station was 10.37 inches with 5.63" falling between May and October. Total precipitation in 1964 was 9.18

inches, slightly under average, while total precipitation in 1965, the first year of study, was 13.31 inches -3" above normal and the highest annual precipitation in the last ten year period.

Data obtained on the excessive amount of precipitation accumulated during 1965 were considered unusable. The study was repeated through the 1966 season to obtain more normal readings. During the 1966 season annual precipitation totaled only 7.85 inches, far below average; however, the data were considered usable and were analyzed.

Several new surface treatments were included in the second year in order to broaden the scope of the study and to determine if an experimental mulch binder was effective in reducing soil moisture evaporation. The new mulch and binder treatments used were Gelgard, a water swellable plastic, Silva-Fiber, Silva-Fiber with Gelgard and Silva-Fiber on Gelgard. Treatments previously used were straw with asphalt binder, and pitted areas where measurements were taken in pit bottoms and on ridges between pits and on bare ground.

RESULTS AND RECOMMENDATIONS - Independent analysis was made on north and south exposed slopes in regard to temperatures as affected by surface treatment. On the cooler north exposure, Gelgard surface treatment produced the highest soil temperature. Bare ridges between pits and the bare control produced surface temperatures significantly higher than pit bottoms. No significant difference appeared among the other treatments on the north exposure.

Three treatments were compared on the south exposure. They included Silva-Fiber, straw, asphalt and bare control. Silva-Fiber and the bare control produced temperature readings not significantly different from each other but both were found higher than straw with asphalt binder which produced the lowest soil surface temperatures on the south exposure.

Soil surface temperatures fluctuated drastically and rapidly with local weather conditions such as wind direction and cloud cover; therefore, soil surface temperatures between treatments were logically comparable only at a specific time while weather effects were similar on all surfaces.

Evaluation of temperature data shows that differences caused by surface treatment are minor on north slopes but are very influential on south exposed slopes which directly face the sun. Again straw and asphalt produced the coolest soil surface temperatures on south slopes.

Analyses of soil moisture data as affected by soil surface treatment were also run.

Soil moisture was found to be adequate below the two-inch depth at any time under any treatment on any exposure throughout the summer season with the exception of several bare control plots which were relatively dry below the 2 inch depth in August and September. This suggests that seedings with an early start in spring should have little difficulty in acquiring adequate soil moisture through the spring growing season at this location. It also suggests that on cuts and fills, surface moisture is replenished by the lateral movement of water as well as precolation of precipitation through the slope surface.

Because straw and asphalt mulching materials are available in Montana at reasonable prices, and because straw and asphalt apparently perform as well or better than other mulches tested, it was recommended to the Highway Reseeding Committee that straw with asphalt binder be used in contract mulching.

Job #5. INDIVIDUAL PLANT SPECIES EVALUATIONS

INTRODUCTION - Results and interpretations from the roadside surveys of 1964 provided the first tangible nnd specific information for the Highway Reseeding Committee (the roadside seeding advisory body) to use in recommending or eliminating certain species and special provisions for highway department contract seeding specifications. In an effort to provide more specific information, a study of prospective species of forbs and grasses suitable for roadside plantings was begun following this roadside survey and has continued through the duration of the project. Propagation of plants for seed production is carried on at the Bridger Plant Materials Center, an affiliate of the Montana Agricultural Experiment Station.

Species evaluation plots were set out at three different locations in three different years. The intent of the species evaluation study was: (1) to determine earliness of establishment and (2) to evaluate competitive ability for various species of grasses, forbs and shrubs.

PROCEDURES - Species plots were initially set out in the Townsend area to evaluate twenty-nine species of various grasses and forbs. Species were planted in replicate plots on a southern exposed 3:1 slope in both spring and fall. Spring trials were set out on May 15, 1966, following the hard-freeze season, and were evaluated ocularly each week throughout the growing season.

A second series of species evaluation plots were set out in the spring and fall of 1967 at the Roundup research area on a consistently poor, hard, light grey soil on a 3:1 north exposure. Planting time was April 11, 1967, more than a month earlier than that for the Townsend series. Both seed and seedlings were subjected to hard freezes. A comparable fall series was set out in the same research area on November 11, 1967. The fall series contained several more species than its spring counterpart.

A third spring-fall seeding and species evaluation was conducted at the Cardwell research area in the fall of 1968 and spring of 1969. A variation in the plot design included the seeding of three species per plot, each being intentionally different in vegetative characteristics for ease in identification. Forbs, shrubs and grasses were included in this series of trials.

RESULTS AND RECOMMENDATIONS - The results obtained from the various species evaluation series were extremely variable as affected by both location and year and season of seeding. The Townsend species trials proved to be very disappointing. The total annual precipitation during 1966, the year of establishment was unusually low (7.85 inches as compared to 10.37 inches for an average year), and response was limited only to the cool season wheatgrass species. By the end of the first growing season, not one of the most favored wheatgrass species rated satisfactory. Fall seedings at the Townsend site examined during the following spring were also disappointing and not worthy of the evaluation time expended.

Species response in the early spring seeding at the Roundup site was greater than expected (Table 15) . Only two species out of a total of 32 planted failed to respond. However, the evaluation of the extensive fall planted series in the same area through 1968 was discouraging (Table 16). Only a few species made a showing, and of the 50 species tested, only ten finally made a stand, six of these being rated as unsatisfactory and four as acceptable. The acceptable species in

Table 15. Roundup species competition trials, seeded April, 1967.

	EVALUATION DATE			
Species	5/20/67	9/20/67	7/8/68	8/27/69
Foxtail barley	5[1]	4	6	3
Mandan ricegrass	5	2	6	4
Canby bluegrass	5	6	9	7
Saltgrass	8	8	8	5
Sand dropseed	9	4	5	4
Vetch species	4	4	4	4
Sudan grass	10	2	10	10
Green needlegrass	8	4	4	4
Tall oatgrass	2	4	3	3
Nuttalls saltbush	8	3	3	6
Canada wildrye	9	4	4	3
Tall wheatgrass	2	2	3	2
Streambank wheatgrass	2	2	3	2
Whiteflowered prairie clover	2	2	4	4
Hard fescue	3	3	3	2
Indian ricegrass	5	3	3	3
Western wheatgrass	4	4	5	4
Meadow foxtail	2	4	7	6
Prairie sandreed	10	4	2	4
Orenburg alfalfa	2	4	1	1
Bluebunch wheatgrass	10	10	10	10
Cicer milkvetch	2	3	1	2
Black medic	2	3	1	4
Alta fescue	2	2	2	2
Penngift crownvetch	7	4	4	6
Crested wheatgrass	2	2	3	2
Siberian wheatgrass	2	1	3	1
Bulbous bluegrass	2	5	6	10
Perennial ryegrass	4	2	5	4
Slender wheatgrass	2	3	4	2
Smooth bromegrass	10	7	2	3
Chewings fescue	2	4	2	2
Sandberg bluegrass	-	9	5	6
Alpine vetch	-	10	10	10
Annual wheatgrass	-	6	5	10
Yellow hop clover	-	10	10	10
Winterfat	-	8	5	6
Fourwind saltbush	-	10	7	5
Needleleaf sedge	-	10	10	10

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[1] Rating scale 1-10 (1-Best)

Table 16. Roundup species competition trials, seeded November, 1967.

Species	EVALUATION DATE 8/27/68	 8/19/69
Ticklegrass	10[1]	10
Beardless wildrye	10	9
Orchardgrass	9	7
Green needlegrass	10	10
Cicer milkvetch	5	5
Tall oatgrass	9	6
Astragalus species	10	10
Meadow barley	8	6
Winterfat	10	10
Bulbous bluegrass	10	9
Yellow hop clover	10	10
White flowered prairie clover	8	9
Prairie sandreed	9	8
Alkali sacaton	9	8
California poppy	10	10
Goldenrod	10	10
Nuttalls saltbush	10	10
Double dianthus	10	10
Vetch species	10	9
Cyanus	10	10
Squirrel tail	7	9
Single dianthus	10	10
Penngift crownvetch	10	8
Phlox	10	10
Indian ricegrass	6	5
Yucca	10	10
Sand dropseed	10	10
Red threeawn	10	10
Squawmat	10	10
Rubber rabbitbrush	10	10
Golden weed	10	10
Goldenrod	10	10
Canada wildrye	5	4
Broom snakeweed	7	5
Waxleaf penstemon	10	10
Sainfoin	8	8
Lupine	10	10
Threadleaf sedge	10	10
Fourwing saltbush	9	8
Nastursium	10	10
Nuttalls alkaligrass	9	10
Gaillardia	10	10
Chewings fescue	8	8
Black medic	9	9
Mandan ricegrass	7	7
Moss rose	10	10
Yellow pea	10	10
Fringed sagewort	10	10
Cudweed sagewort	9	9
Field sagewort	8	7

[1] Rating scale 1-10 (1-Best).

the fall planting were Indian ricegrass, Canada wildrye, Cicer milkvetch and broom snake weed. Evaluation of the Roundup species competition trials continued through the 1969 growing season. The early spring broadcast seeded plots attracted wide attention by various agencies and were observed closely to determine the performance of species during the second and third growing seasons as compared to those species that were outstanding during the first growing season.

Evaluation results for the Cardwell species mixture plots are shown in Table 17.

These three sets of species trials substantiate the importance of early seeding, for the very early seeding dates produced a good stand of a wide variety of species. Late seeding has been disappointing with some exceptions at Cardwell.

The very successful and productive Roundup spring species series has shown that it is both possible and practical, at least under some semiarid growing conditions, to seed at a heavy rate to obtain a dense stand of grass seedlings and to rapidly achieve initial soil stability. This stand will thin itself out to allow surviving seedlings to grow and develop to mature form while maintaining the soil stability achieved during the initial spring. This series made clear that this feat can be accomplished with not one but with many of the different species tested, including legumes such as prairie clover and alfalfa. It substantiated the possibility of using dryland non-forage type grasses of short conformation for use in medians and inslopes to reduce the need for mowing.

These trials also demonstrated the effectiveness of a number of species that have not been generally used on poor non-amended soil types

Table 17. Evaluation of Fall-Spring species seeding trials at Cardwell at the end of the first growing season, Fall, 1969.

Species Mixture	Replication I Fall 10/19/68	Replication I Spring 3/17/69	Replication II Fall 10/19/68	Replication II Spring 3/17/69
Tall wheatgrass* Mandan ricegrass Fourwing saltbush	6[1/]	5	8	6
Basin wildrye Thickspike wheatgrass* Nomad alfalfa	4	7	7	6
Prairie sandreed Slender wheatgrass* Sainfoin	6	8	7	9
Nuttalls saltbush Draylar bluegrass Fairway crested wheatgrass*	6	7	7	6
Sweetclover Kenmont fescue Lincoln bromegrass*	8	8	8	4
White flowered prairie clover Hard fescue* Winterfat	9	8	9	6
Buffalograss Western wheatgrass* Cicer milkvetch	9	7	7	9
Rabbitbrush Siberian wheatgrass* Alkali dropseed	5	7	5	7
Canada wildrye Orchardgrass* Needleleaf sedge	9	9	7	6
Pampian bromegrass* Bitterbrush Blue grama	9	10	8	8
Indian ricegrass* Field sagewort Gardner saltbush	9	10	6	9

[1/] Rating scale 1-10 (1-Best)

* Dominant responding species.

typical of roadsides. They demonstrated unexpected broad tolerance of other species such as meadow fescue and orchard grass to unusually dry alkaline roadside conditions.

Job #6. FERTILIZER EVALUATIONS

INTRODUCTION - At the start of the project in 1964 there was general agreement among the Advisory Committee that fertilization of native grasses was not particularly necessary or justifiable under semiarid conditions because of the ability of native species to adapt to dry soils of low fertility. It was also felt that any fertilization on roadsides would invigorate the invading weed population far more than the seeded grasses and therefore might create or exaggerate unnecessary competition for scarce moisture between invading and seeded species. However, the very poor development of seedings of 1965 at the Townsend site suggested that, in addition to soil moisture, species and time of seeding, a more complete knowledge of the effects of fertilizer on native grasses was needed.

Portions of roadsides seeded in spring of 1965 demonstrating disappointingly slow development were fertilized on a restricted trial plot basis with 150 lbs/acre of 16-20-0 fertilizer in the early spring of 1966. Plots fertilized were selected from various cuts, fills, slopes and exposures. Very rapid and conspicuous improvement of grasses became apparent within the treated plots. By fall of the same season, response of grasses to fertilizer was dramatic, showing good height growth and abundant seedhead production. Unfertilized vegetation remained seriously depressed and without seedhead development.

The obvious response of this initial fertilization attempt, even with delayed application, prompted the development of fertilizer demonstration plots within various Highway Department Divisions to show the improvement made by fertilizing old and decadent contract seeded areas. Demonstration fertilizer plots have been made each season and presently exceed twenty-four locations. Some of these have influenced recommendations by the Highway Research Committee and thus have been included as actual seeding specifications.

In addition to the demonstration plots, intensive fertilization trials were initiated at the Roundup and the Cardwell research site to provide information essential in designing a practical fertilizing program that would best fit into the busy maintenance schedule of highway personnel.

The Roundup series included treatments to compare various time-of-seeding and time-of-fertilizing combinations. A secondary purpose was to compare individual species response to time of fertilization. This effect is a prime consideration in adjusting a fertilizing program to mesh into an established schedule of highway maintenance.

The primary intent of the Cardwell series was to determine the response of vegetation to spring and fall applications of the nitrate and sulphate forms of nitrogen. Under usual conditions, the nitrate form should be immediately available to plants, whereas the sulphate form must be transformed to a soluble state by bacterial action following soil warm-up in the springtime. It was thought that a distinct advantage might be realized by using a non-leaching type fertilizer that could be applied in the fall but would not become available to the plants until the following spring, the most optimum time. Fall applications of fertilizer would fit better into the present maintenance schedule of highway personnel.

PROCEDURES - In 1967, a series of fertilizer trials including types, amounts, and time of application were set out in the Roundup research site. Treatments consisted of:

I. Early spring drill seeding (April 11, 1967)
300 lbs/acre rate of 16-20-0 broadcast each month on separate plots in the months of April, May, June, September, October, November.

II. Early spring drill seeding (April 11, 1967)
125 lbs/acre 18-46-0 broadcast at time of seeding and 84 lbs/acre 33.5-0-0 supplemental fertilizer applied in the months of April, May, June, September, October, November.

III. Drill seeding in months of April, May, June, September, October, November, and fertilizing with 300 lbs/acre rate of 16-20-0 following the drill seeding.

Ocular evaluations of response to seeding and fertilizing time were maintained for a three year period.

The fertilizer trial series placed in the Cardwell research area was initiated in the fall of 1968 and spring of 1969 before the full implications of the Roundup study were realized. The following fertilizer treatments were applied on a top-soiled south exposure previously seeded to a broad mixture of grass species. Amounts of fertilizer applied were at a per acre rate equivalent to 40 lbs. available nitrogen and 50 lbs. available phosphorus.

A.	Fall fertilization	NH_4NO_3 & P_2O_5	10/19/68
B.	Spring fertilization	NH_4NO_3 & P_2O_5	3/17/69
C.	Fall fertilization	NH_4SO_4 & P_2O_5	10/19/68
D.	Spring fertilization	NH_4SO_4 & P_2O_5	3/17/69
E.	No fertilization	A seeded control	

This series of plots was examined in the fall of 1969 after the first growing season.

RESULTS AND RECOMMENDATIONS - An abbreviated table summarizing the occular evaluation of the treatments in the Roundup study using a rating scale of 1-10 (1 best) is included as Table 18. Differences in response became obvious and trends were apparent the first season. The most productive combination of time-of-seeding and time-of-fertilization was the earliest drilled seeding accompanied with earliest broadcast fertilization. Supplemental applications of fertilizer on established plots produced no apparent advantage. In fact, a reduction in stand density was noted as the second season (1968) progressed where fertilizer was applied late. By fall, it was evident that late application was apparently damaging; it had eliminated the crested wheatgrass. Meadow fescue became the dominant species remaining from the mixture planted. These unanticipated results indicated the need for a continued and more sophisticated fertilizer study program.

Plots drill seeded and fertilized during the same month were most impressive during the first two seasons. The April seedings with fertilizer clearly had a distinct advantage over May seedings with fertilizer; the latter was judged as marginally acceptable. June seedings were decidedly unacceptable as were the September seedings. October seedings were considered acceptable, but by this time, emergence in both the June and September plots had progressed to a marginal degree. November seedings did not germinate until the following spring. The advantages of the early spring seeding, including the important advantage in time, were less obvious during the third season.

Evaluation of the Cardwell fertilization plot series is still continuing but it appears at this time that fall fertilizing with ammoniam sulphate is a promising possibility. All fertilized plots supported a

Table 18. Abbreviated ocular evaluation of 1967 fertilizer trials at Roundup.

Evaluation Date	Month					
	April	May	June	September	October	November
Seeded and Fertilized in Month of:						
10/15/67	2[1]	8	10	10	-	-
9/22/68	2	6	8	7	6	5
8/27/69	3	4	9	8	8	7
Seeded and Fertilized in April with Supplemental Fertilizer Added in Month of:						
10/15/67	3	5	7	6	-	-
9/22/68	4	6	8	8	8	8
8/27/69	5	8	10	9	8	8
Seeded in April but Fertilized in Month of:						
10/15/67	2	4	8	9	-	-
9/22/68	3	5	8	8	7	6
8/27/69	4	8	9	8	7	7

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[1] Rating scale 1-10 (1-Best)

Table 19. Ocular evaluation of fertilizer plots at Cardwell[1].

Treatment	Replication					
	I	II	III	IV	V	VI
A. $NH_4NO_3 + P_2O_5$ - Fall	7[2]	7	7	8	6	7
B. $NH_4NO_3 + P_2O_5$ - Spring	8	7	8	7	6	6
C. $NH_4SO_4 + P_2O_5$ - Fall	6	5	6	7	6	6
D. $NH_4SO_4 + P_2O_5$ - Spring	7	4	6	6	7	6
E. Seeded Control	8	7	8	6	7	7

[1] Fertilized in the fall of 1968 and spring of 1969; evaluated in the fall of 1969.
[2] Rating scale 1-10 (1-Best).

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very dense lush stand of firebush which completely obscured the grasses beneath. Unfertilized plots were conspicuously less productive in both firebush and grass. The response of the seeded grasses should be more clearly apparent once the stand of annual firebush is substantially reduced by competition of the grass seedlings. Table 19 contains ocular evaluation of the plots.

Job #7. SOIL INOCULATION TRIALS

INTRODUCTION - It was suggested that in addition to soil nutrients, sterile newly-constructed highway slopes may be lacking in the bacteria necessary for the development of a rapid stabilizing cover. Soil bacteria are particularly important as a necessary component in the nitrogen-fixing processes of legumes. Such bacteria can be introduced into the soil by inoculation of the soil with a material which contains the specific bacteria needed.

A study was undertaken at the Roundup research site in an effort to determine whether bacterial inoculation was beneficial or indeed necessary in order to accomplish a quick and satisfactory cover on roadsides.

PROCEDURES - Commercial soil inoculant materials were obtained for testing in conjunction with various commercial fertilizer combinations. The materials used were "Soil Life", a bacterial type soil conditioner, and a broad mixture of soil inoculants received from the NITRAGIN Company. These products were included in a series of test plots separately and together, at several concentrations, and with various combinations of fertilizers in order to test their relative merits. Some materials were applied in water solutions using the hydroseeder while other materials were applied dry by broadcasting.

Both organic and inorganic types of nitrogen fertilizer were used because it was thought that the inorganic form might cause a different response than the organic type. Ammonium nitrate, referred to as "nitrogen", was used as the inorganic chemical form and urea was the nitrogen source. The solid fertilizers were broadcasted onto the various plots and the Soil Life and other soil inoculants were applied in water solution with the hydroseeder.

RESULTS AND CONCLUSIONS - Results of this study were reflected during the first year by dominant growth of invading firebush, and the second year by the seeded grasses. Good to excellent response was apparent in every plot that included an application of commercial phosphorus. Without phosphorus, however, no appreciable cover of any kind was produced even though soil inoculants were applied. Differentiation between plots that received double and triple amounts of Soil Life and soil inoculants was not discernible from untreated plots unless phosphorus was included as a treatment ingredient. Similar observation persisted through the 1969 growing season.

Neither the Soil Life bacterial product nor the mixture of soil inoculants used provided any apparent practical advantage in producing cover on sterile sites. Consequently, it was concluded that in the vicinity of the research area of this study, available phosphorus was the limiting element in promoting vegetational growth. This response substantiated earlier soil testing but produced no helpful information on the merits of the bacterial products tested. The experiment was considered non-productive in this respect, and these bacterial materials are not presently recommended for use on roadsides. Phosphorus as a fertilizer constituent with nitrogen is strongly recommended for the Roundup vicinity in any roadside fertilizing program.

Job #8. EVALUATION OF MULCHES AND BINDERS

INTRODUCTION - Several mulch materials were included in the various treatments used in the Soil Temperature and Moisture Relationship studies in the Townsend area (reported previously as Job #3). Loss of mulch from wind and the need for limiting mulching operations to the windless, inconvenient periods of very early morning dramatized the need for modified mulch materials as well as new mulching techniques. This provoking series of experiences with mulching promoted the experimental testing of Gelgard as a binding agent. Gelgard is a commercial water thickener produced by Dow Chemical and marketed as a fire suppression agent. It was included in the later Townsend moisture trials as a material which might seal the soil surface and reduce soil moisture evaporation without inhibiting the passage of precipitation into the soil.

Gelgard is a fine white powder which when exposed to water absorbs and swells to form a thick clear liquid. Used as a mulch by itself, this thick, clear, viscous pudding-like material dried to form a skin or crust on the soil which tended to reduce soil moisture loss through evaporation. Initial seed germination testing in various concentrations of Gelgard solutions conducted in the laboratory verified that the material was nontoxic to plant life. It also performed well in the laboratory when subjected to repeated wetting and drying. However, on roadsides where it was subjected to driving wind and rains, the water swellable plastic did not return to the original thick pudding stage as predicted, but formed small soil covered balls. These pellets promptly rolled down the slopes and the desired effect was lost.

A Gelgard coating placed between the soil and a mulch layer of Silva-Fiber provided a more lasting seal, but the duration of the layering system was not considered sufficient to warrant the separate application and expense involved.

Gelgard, when added to wood cellulose fiber mulches as a constituent of the slurry produced results so much better than anticipated that all other systems with Gelgard were discontinued.

Distinct advantages provided by adding Gelgard to the slurry are:

1. A resilient, spongy, resistent, but absorbent mulch blanket was formed that had an effective life span in excess of two growing seasons. (This blanket could be removed in large pieces when damp from smooth surfaces and rolled up into sizeable sheets.) Without the use of Gelgard as a binder, mulches seldom lasted or remained in place through a single winter season following late fall application.
2. The water thickening action of Gelgard reduced seed dropout and produced a more effective seeding job. It increased seeding range by reducing excessive spray after it left the hydroseeder nozzle. A compact column of slurry mixture increased accuracy of mulch and seed placement.
3. Working time was extended considerably into the windy part of the day because the thickened water slurry was controllable, even in a mild breeze.
4. The lubricating effect of the Gelgard slurry mixture improved the mechanical operation of the hydroseeder, materially improved suspension of mulch in the slurry and substantially reduced plug up and breakdown time losses.

Several distinct disadvantages also became apparent with the use of Gelgard. The lubricating effect of Gelgard was obvious both inside and outside the hydroseeder. The working platform of the machine became exceedingly slippery when spillage was allowed to occur. Also, the dried plastic binder clings tenaciously to most any surface, including the hydroseeder and operator, and becomes difficult to remove once it has dried. Perhaps the greatest disadvantage of Gelgard as a mulch binder is the fact that its viscous consistency is very drastically thinned by the addition of a minute amount of salt. By adding chemical fertilizers containing salts to the slurry mixture, the binder effect of the Gelgard is lost.

Dacagin, an herbicide drift control agent produced by Diamond Shamrock Corporation proved to have great potential. The consistency of the Dacagin mixture was not pudding-like as produced by Gelgard, but rather a slick, viscous, stringy consistency which imparted the advantages of Gelgard without breakdown when fertilizers were added to the slurry. Another material, Coherex, a yellow, sticky asphalt resin, seemed to have possibilities as a mulch binding agent.

Aquatain, a liquid plastic, was tested but not as a binder. It was sprayed on the soil surface according to directions to form a thin plastic film. This film was intended to control erosion while allowing precipitation to percolate through the film into the soil.

To gain a meaningful comparison and evaluation of these various available mulches and binders and mulching techniques, an extensive test plot series was set out in the Huntley research area in the spring of 1968. Normal annual precipitation is 11.48 inches at this location.

PROCEDURES - North and south exposed slopes of a 2½:1 gradient, all recently topsoiled, were staked into 50' wide plots cultivated with a Klodbuster, broadcast seeded, and Klodbustered again to cover the seed. Mulch treatments were applied within plots on the seeded roadsides.

Included in the array of treatment replications were:

1. Straw and asphalt
2. Straw stubbled
3. Asphalt (SS-1 R.C.)
4. Silva-Fiber, green
5. Silva-Fiber, black
6. Gelgard with Silva-Fiber, green
7. Gelgard with Silva-Fiber, black
8. Dacagin with Silva-Fiber, green
9. Dacagin with Silva-Fiber, black
10. Coherex with Silva-Fiber, green
11. Aquatain
12. Seeded check plot

Evaluation of treatments for soil stabilization effectiveness at the end of the first and second growing seasons was judged ocularly as based on the following criteria:

1. eroded sediment accumulation at the base of plots reflecting mulch erosion control efficiency
2. amount of desirable permanent vegetative cover produced
3. amount of temporary invading cover produced

RESULTS AND CONCLUSIONS - Table 20 containing the 1968 and 1969 evaluations of the mulching and binder comparison trials is attached. Mulching systems are ranked in order of their total effectiveness.

It was concluded from these tests that a carefully applied mulch of clean straw (1500 lbs/acre) with asphalt binder (300 gallons/acre SS-1, RC) is an effective economical mulching system when applied in areas known to be relatively free of strong winds and where slopes are not so extensive in height as to be beyond the effective limits of the mulch spreader equipment. The major objection causing the unsatisfactory rating of straw with asphalt binder was the appearance of weeds during the second growing

Table 20. Comparison of April, 1968 mulching treatments at Huntley.

		Northern Exposure						Southern Exposure					
		Fall 1968			Fall 1969			Fall 1968			Fall 1969		
Treatment	Rank	Rep 1	2	3	Rep 1	2	3	Rep 1	2	3	Rep 1	2	3
Straw with Asphalt Binder	4	3[1]	1	1	4	4	7	1	2	1	8	7	7
Straw Stubbled	10	1	1	1	8	6	8	1	1	2	8	8	8
Asphalt (SS-1 RC)	9	3	4	3	5	4	3	3	3	2	5	8	6
Silva-Fiber (Green)	6	4	3	5	3	2	4	2	6	4	5	7	5
Silva-Fiber (Black)	5	4	5	4	2	4	4	3	3	3	4	5	5
Gelgard with Silva-Fiber (Green)	1	2	2	2	3	2	3	2	2	2	5	8	5
Gelgard with Silva-Fiber (Black)	2	3	2	5	2	4	2	2	3	3	5	4	5
Dacagin with Silva-Fiber (Green)	3	3	6	5	3	3	3	2	2	3	7	6	6
Dacagin with Silva-Fiver (Black)	7	5	5	4	2	3	4	2	2	3	6	6	5
Cohex with Silva-Fiber (Green)	8							2	2		5	6	
Aquatin	11							6	6	8	7	9	7
Seeded Check Plot	12	9	9	8	5	5	7	9	8	6	8	8	8

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[1] Rating scale 1-10 (1-Best).

on dry south slopes. This condition might have been caused by a number of factors, for all treatments on southern exposures became relatively weedy during that season. Erosion control with the straw and asphalt was as effective as any other treatments. The availability of materials and cost of application methods makes straw and ashpalt a reasonable and economical approach to mulching within the limits of the system. However, a mulching job carelessly applied might be far out-performed by other treatments.

Beyond reasonable limits of efficiency of straw and asphalt or in very windy country typical of certain areas of Montana, a choice of mulching systems is indicated from these tests as a substitute. Green Silva-Fiber or black Silva-Fiber with Gelgard binder, or green Silva-Fiber with a Dacagin binder all appear as effective mulching systems. These three combinations are comparable economically. The accompanying fertilizing program may determine the mulching system used, for the salts in chemical fertilizers will destroy the binding qualities of Gelgard while the Dacagin seems not to be affected. A change of fertilizer to an organic type may eliminate this difficulty, or not fertilizing until after seedling emergence and adequate cover establishment may be an alternative.

Job #9. TIME-OF-SEEDING

INTRODUCTION - As indicated previously (see Job #5) one of the most important results of the original Townsend species trials was the realization of how critical the timing of roadside seeding can be, particularly on exposed south-facing slopes.

Very early spring seeding (in March and April) is similar in many respects to late fall seeding after October 15 in much of Montana; both early spring and late fall are characterized by severe sudden blizzards and hard freezes with intermittent periods of warm days and cool nights. Radiation is extreme. Seeding conditions are unpredictable, and generally are neither conducive to the use of usual seeding equipment because of frozen ground, nor hydraulic seeding methods because of frequent freezing temperatures and freeze-up break-downs.

Two approaches seemed logical as a possible solution to the time-of-seeding dilemma. First, the soil and moisture relationship investigations (see Job #4) demonstrated good germination of seed in the bottoms of pits in the pitted plots, and moisture was found adequate near the surface through most of the short growing season. These findings indicated that the possibility of drilling seed into a deepened furrow might be a realistic approach for extending the spring seeding season. On the strength of this experimental evidence, plans were drawn and approved for the remodeling of a deep furrow drill into a pit drill. The second approach to the time-of-seeding problem was one fundamentally of species selection. Species that were both fast germinating and fast developing would have a definite advantage in survival by establishing themselves in early spring before the available surface soil moisture evaporated. Work began on both approaches early in the project.

PROCEDURES - A deep furrow drill was modified by cutting a wide model drill in half, and then creating a drill with two drill boxes and two ranks of listers one behind the other independently. The rear rank of listers were positioned alternately with the front rank. Each rank was raised and lowered into working position by a series of cams operated from the power-take-off of the towing tractor. Valves controlled the hydraulic cylinders which raised and lowered the two ranks of listers. Seed was dropped from the seed boxes through tubes behind the listers when they were in operating position. Alternately arranged elongated pits approximately four feet long by 8 inches deep were formed and seeded by this machine as it was drawn along. It was used primarily on slopes less than 2½ to 1 because of stability problems.

The species selection approach to the time-of-seeding problem was discussed previously as part of Job #5 and #6 in this report. Species trials were made at Townsend and at the Roundup and Cardwell research sites described earlier under Job #5. Time-of-seeding trials were also included as an integral part of the Roundup fertilizer study. This later series of tests consisted of replications of seeding in April, May, June, September, October and November with a fertilizer application of 300 lbs/A rate of 16-20-0.

At the Cardwell research site, 1969 time-of-seeding trials were included to further substantiate the advantages of spring seeding on steep south-facing slopes in semiarid country, first suggested by the contract seeding evaluation study.

RESULTS AND CONCLUSIONS - Results achieved with the pit drill were very inconsistent; however, seeding trials continued with it until it became substantiated by other time-of-seeding trials that the risks involved by extending the spring seeding season into May and June were so great that the species selection approach seemed far more realistic. Use of the pit drill machine was discontinued in 1968.

Species testing and selection is still continuing. Results from the Townsend, Roundup and Cardwell studies on specific species are given under Job #5, and the time-of-seeding study at the Roundup research site is discussed under Job #6. Comparison of seeding dates at the Roundup location were dramatic with the April seeding far surpassing any other time of seeding for the first three growing seasons. These comparisons appear in Table 18. Evaluations of the Cardwell time-of-seeding tests appear in Table 21. The most outstanding development of all the Cardwell plots appeared in the March seedings followed by the April seedings. May seedings were judged as marginally acceptable and June unacceptable. Fall seedings did not germinate until the spring of 1970.

Time-of-seeding experimentation thus far has been limited to the central portion of Montana. It is expected to be far more critical toward the warmer eastern portion of the state. Studies there are being planned.

Table 21. Evaluations of 1969 Time-of-seeding plots on steep south exposure at Cardwell.

	Evaluated 11/15/69		
Month	Rep I	Rep II	Rep III
March	4[1/]	2	4
April	6	5	6
May	9	8	7
June	9	10	9
September	-	-	-
October	-	-	-
November	-	-	-

[1/] Rating scale 1-10 (1-Best)

Job #10. NATIVE SHRUB PROPAGATION BY CUTTINGS

Involvement in species selection for the purpose of stabilizing roadside slopes brought about the realization that vegetation other than grasses and forbs may be equally or even better adapted to many of the particular problem sites and soils along Montana highways. However, a ready source of promising plant materials other than grasses was practically non-existant.

It was thought that available information on effective propagation methods for native shrubby species might encourage local nurseries to realize the market potential and produce this type of planting stock. The objective of the native shrub propagation study was to provide such information.

PROCEDURES - A simple greenhouse study was initiated which required the building of a high-humidity mist propagation bench. Cuttings of native shrub species were collected every month of the late fall, winter, and spring and placed in the mist bench. A list of the species collected is shown in Table 22. The treatments used to induce rooting included scarification, use of iodolacetic acid (a root-promoting hormone), and no chemical or mechanical treatment as a control.

Data read and recorded on rooting response by species included the following:

1. Species
2. Collection date
3. Treatment date
4. Reading date
5. Age of wood sampled
6. Nodal or internodal
7. Treatment
8. Survival
9. Callousing dates
10. Number of roots developed
11. Average length of roots

Table 22. Percent survival of species by collection periods for the shrub propagation study.

Species	Collection Period	Plants			Percent Survival
		Live	Dead	Total	%
Kinnikinnik	April-Sept.	75	127	202	37
Silver sagebrush	Dec. & Jan.	18	22	40	45
	Feb. & March	61	59	120	44
Cudweed sagewort	April-Sept.	0	73	73	0
Big sagebrush	April-Sept.	3	73	76	4
Oregon grape	April-Sept.	5	12	17	29
Bog birch	April-Sept.	12	58	70	17
Common caragana	Feb. & March	20	130	150	13
	Dec. & Jan.	32	81	131	28
Maximowitz caragana	Oct. & Nov.	38	82	120	32
	Dec. & Jan.	83	33	116	72
	Feb. & March	20	90	110	18
Pygmy caragana	Oct. & Nov.	23	43	66	35
	Dec. & Jan.	20	121	141	14
	Feb. & March	8	105	113	7
Mountain mahogany	April-Sept.	0	60	60	0
Rubber rabbitbrush	Feb. & March	0	195	195	0
	April-Sept.	0	84	84	0
Western white clematis	Oct. & Nov.	14	46	60	23
	Dec. & Jan.	29	84	113	26
	Feb. & March	55	85	140	39
	April-Sept.	16	138	154	10
Canadian clematis	Feb. & March	43	83	126	34
Red stemmed dogwood	Dec. & Jan.	24	36	60	40
	Feb. & March	40	6	46	87
	April-Sept.	113	67	180	63
Hawthorn	Dec. & Jan.	0	40	40	0
Silverberry	Dec. & Jan.	2	28	30	7
	Feb. & March	2	88	90	2
Sea buckthorn	Oct. & Nov.	62	56	118	53
	Dec. & Jan.	39	17	56	70
	Feb. & March	39	21	60	65
Hops	Dec. & Jan.	27	0	27	100
	April-Sept.	33	103	136	24
Common juniper	Feb. & March	46	48	94	49
	April-Sept.	58	20	78	74
Horizontal juniper	Oct. & Nov.	20	0	20	100
	Dec. & Jan.	229	22	251	91
	Feb. & March	244	25	269	91
	April-Sept.	232	430	662	35
Rocky Mt. juniper	Feb. & March	6	15	21	28
Matrimony vine	Oct. & Nov.	78	25	103	76
	Feb. & March	29	220	249	12
Virginia creeper	Oct. & Nov.	28	2	30	93
	Dec. & Jan.	50	11	61	82
	Feb. & March	145	2	147	99
	April-Sept.	45	8	53	85

Table 22. (Continued)

Species	Collection Period	Plants Live	Plants Dead	Plants Total	Percent Survival
					%
Mock orange	Dec. & Jan.	0	60	60	0
	Feb. & March	4	55	59	7
	April-Sept.	0	38	38	0
Ninebark	Oct. & Nov.	13	46	59	22
Silver fleece vine	Feb. & March	7	73	80	9
Buckthorn	Oct. & Nov.	59	0	59	100
Prairie rose	Oct. & Nov.	3	0	3	100
Woods rose	Oct. & Nov.	25	18	43	58
	Dec. & Jan.	14	126	140	10
	Feb. & March	6	6	12	50
	April-Sept.	12	200	212	6
Smooth sumac	Feb. & March	0	26	26	0
Three-leaf sumac	Oct. & Nov.	1	59	60	2
	Dec. & Jan.	0	45	45	0
	Feb. & March	12	176	188	6
	April-Sept.	0	111	111	0
White willow	April-Sept.	10	0	10	100
Arctic willow	April-Sept.	286	13	299	96
Sandbar willow	Feb. & March	70	73	143	49
	April-Sept.	195	410	605	32
Greasewood	Feb. & March	65	98	163	40
	April-Sept.	0	131	131	0
Purple willow	April-Sept.	22	38	60	37
Mountain ash	Feb. & March	0	60	60	0
Snowberry	Dec. & Jan.	33	53	86	38
	Feb. & March	10	22	32	31
	April-Sept.	5	57	62	8
Coralberry	April-Sept.	21	186	207	10
Tamarix	Oct. & Nov.	60	46	106	57
All Species	All Dates	3099	5400	8499	36

12. Root origin (nodal, internodal)
13. Flower buds developed on cutting
14. Number of live buds
15. Length of new growth

A total of eighty-two individual collections were involved in this study. There were four broad categories of collection periods: Period #1, including October and November; Period #2, December and January; Period #3, February and March; and Period #4, April through September. Significance of species reaction by collection dates were determined by Chi Square contingency analysis.

RESULTS AND CONCLUSIONS - Shrub propagation success as reflected by percentage survival for various collection periods, is shown in Table 23, and species reaction by treatment is shown in Table 24. The length of time in the propagation bench was variable depending on species and time of collection. For some periods and for some species, rooting response was very slow, if at all; in other cases a favorable rooting reaction was observed. The excessive variance in speed of rooting led to unpredictable difficulties in stocking and maintaining the propagation facility at peak capacity. Some collections were necessarily eliminated because there was no space left in the bench at the desired time because of unduly slow response of species already there.

Table 23. Summary of survival based on species x treatment x collection period.

	Collection Period																			
	October & November					December & January					February & March					April-September				
	Level of significance			Treatment		Level of significance			Treatment		Level of significance			Treatment		Level of significance			Treatment	
Species	.01	.05	NS	A	B	.01	.05	NS	A	B	.01	.05	NS	A	B	.01	.05	NS	A	B
Kinnikinnik																		*	P	P
Silver sagebrush											*	*			G					
Big sagebrush																		*	P	P
Oregon grape																		*	P	P
Bog birch																*	*		G	
Common caragana								*	P	P			*	P	P					
Maximowitz caragana			*	P	P		*		G				*	P	P					
Pygmy caragana								*	P	P			*	P	P					
Mountain mahogany																		*	P	P
Rubber rabbitbrush													*	P	P			*	P	P
Western white clematis			*	P	P	*	*		P	P			*	P	P			*	P	P
Canadian clematis											*	*		P	P					
Red Stemmed dogwood						*	*		G				*	G	G					
Silverberry								*	P	P										
Sea buckthorn	*	*		G				*	B	B	*	*			G					
Hops																	*		P	P
Common juniper													*		G	*	*		G	
Horizontal juniper																*	*		P	P
Matrimony vine			*	G	G								*	P	P					
Virginia creeper								*	G	G			*	G	G	*	*		G	G
Mock orange													*	P	P			*	P	P
Ninebark			*	P	P															
Silver fleece vine													*	P	P					
Buckthorn			*	G	G															
Woods rose			*	G	G											*	*		P	P
Three-leaf sumac			*	P	P			*	P	P	*	*		P	P			*	P	P
White willow																		*	G	G
Arctic willow																	*		G	
Sandbar willow											*	*			G			*	P	P
Greasewood											*	*			G			*	P	P
Mountain ash													*	P	P					
Snowberry								*	P	P								*	P	P
Coralberry																		*	P	P
Tamarix	*	*			G															

Treatment: A scarification and indolacetic acid
B no mechanical or chemical treatment
P= Poor sirvival
G= Good survival

Job #11. DRYLAND SHRUB PLANTING IN ELONGATED POTS

INTRODUCTION - Shrub planting on roadsides in the semiarid portions of the western states is expensive, characterized generally by high mortality and very slow growth and development of stock. The evaporation potential exceeds annual precipitation by several times in much of the area. Expensive irrigation systems have been installed in some major interchanges and rest stop areas, but the alkaline salts contained in the deep well water sometimes make it unfit for prolonged irrigation purposes.

It is mandatory that more economical and effective systems be devised for providing permanent roadside vegetative cover. As pointed out in previous studies, this may be accomplished in part by empahsizing the importance of species adaptation to prevailing growing conditions. Efforts toward developing new dryland planting methods for shrubby species seemed to be another possible alternative.

Great cost reduction in seedling tree and shrub planting could by achieved by successfully increasing the rate of plant survival, lowering the high cost of planting stock, and reducing the amount of handwork required by the usual standard planting processes. The implications of a planting method conducive to complete mechanization are tremendous and the potential savings make it universally appealing. The purpose of this shrub planting study was to explore such a planting technique. From this initial investigation more intensive and analyzable dryland planting studies will be devised.

PROCEDURES - Successfully rooted cuttings from previous greenhouse work on the propagation of native shrub materials demonstrated root development of some species to be particularly well adapted to rapid longitudinal growth. These plants were saved and transplanted in confining tar-paper pots ; 2" x 2" x 12" in dimension. Late spring planting of these native shrub seedlings after being removed from the impervious pots proved outstanding compared to standard stock.

The initial success of this technique over regular procedures prompted attempts to develop extraordinarily long root systems. Plants were tested in decomposable pots 2½ inches in diameter by 2 feet deep. Approximately 1,000 tubes were filled with potting soil and planted to a variety of nursery stock in preparation for dry roadside testing. These were called "tubelings" to distinguish them from standard control stock. They were kept in the greenhouse for several months until many of the roots reached the bottom of the two foot tubes. A series of plants containing several species of tubed and untubed (control) stock were set out on various slopes in the Logan research area in early summer of 1969. The developed tubelings were set out using a small gas engine powered soil auger which bored holes of approximately the same diameter as the tubelings. This placed active growing roots down into deep soil moisture to sustain the plant. (Figures 10 and 11). Air from around tubes was removed and essential soil contact made with a prying action on the handle of a hog-nosed tiling shovel inserted around the tube at three positions several inches distant from each plant.

The regular planting method (untubed controls) consisted of securing common planting stock from nurseries and setting them out on the slopes with the use of a spade. Precautions were taken to plant the nursery stock at the proper depth and to adequately pack the soil around the roots, but no additional special treatments were provided.

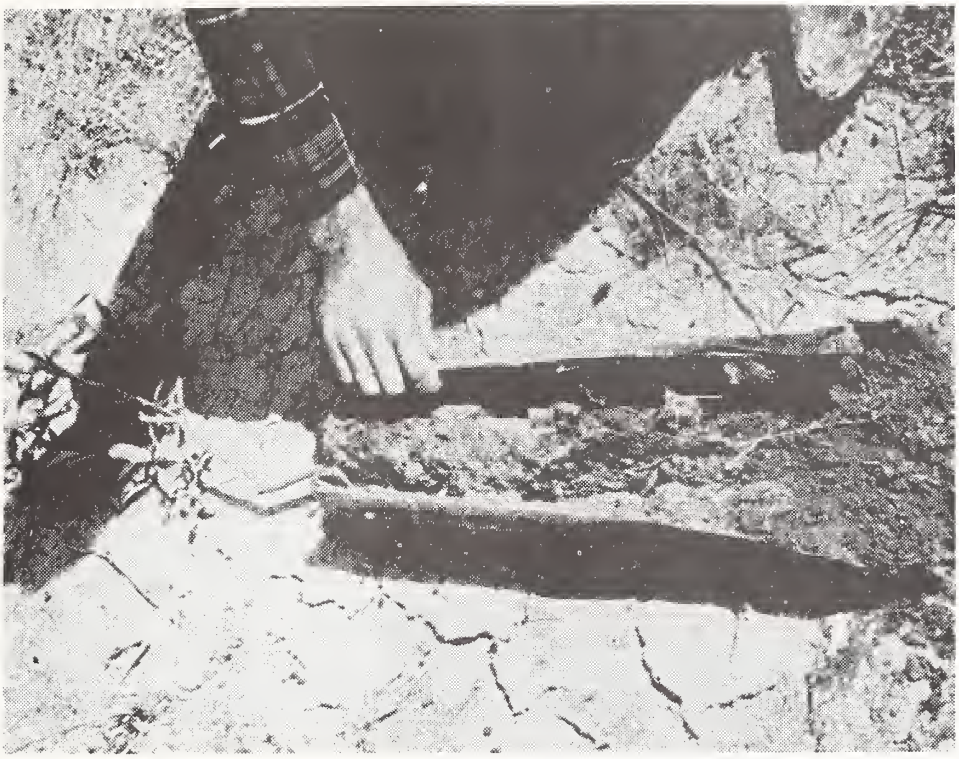

Figure 10. A tubeling split open illustrates the length of the developing root system.

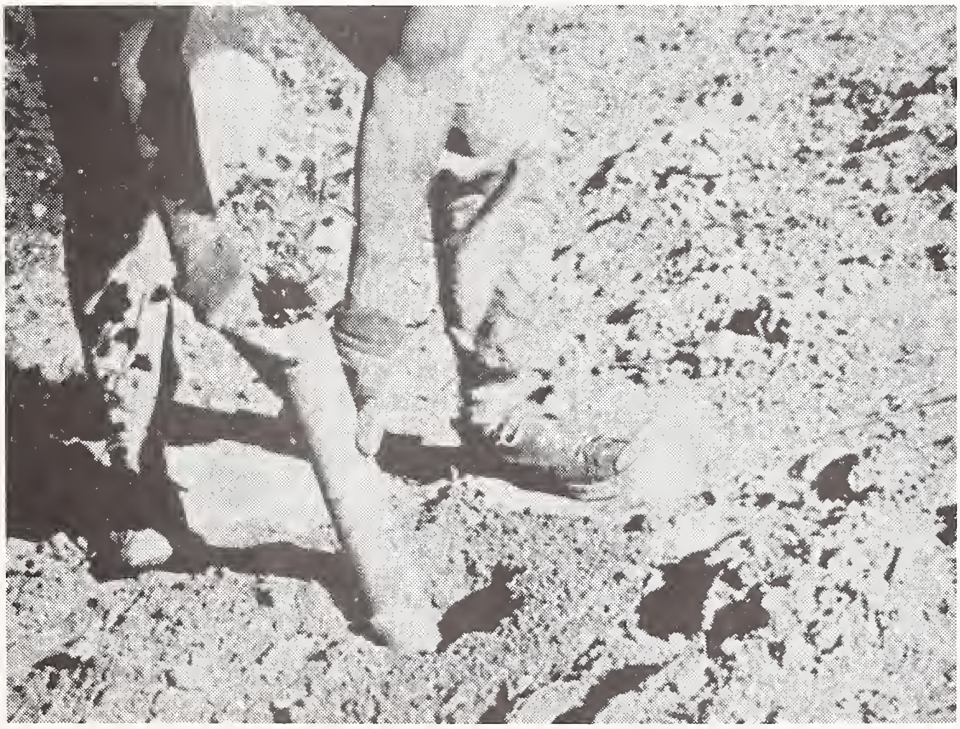

Figure 11. Tubelings are placed in holes drilled in the soil with an auger, minimizing planting time.

The initial tubeling study was evaluated according to survival of plants during the second growing season.

RESULTS AND CONCLUSIONS - Survival comparisons of the tubed and untubed dryland plantings without any irrigation in an arid area (mean annual precipitation 10.3 inches) appear in Table 24. Survival of the tubed plantings greatly exceeded that of the untubed plantings in all instances where comparisons were made. On the basis of this initial study more extensive evaluation of the tubeling dryland planting innovation will be carried out to further investigate the advantages of this technique.

A great deal of practical information was acquired in the initial trials with tubelings. As the root development period progressed, it became more obvious that the composition of the potting tube was less than satisfactory, especially those tubes that were on the outside of grouped tubes as arranged on the greenhouse benches. Tubes within a dense grouping were continually damp and thus became gradually weaker as the root development period progressed, whereas exposed tubes remained dry, crisp and impenetrable.

It also became evident that the degree of success and speed of response in forcing deep root development were a compound function of species, of potting soil texture, and of the composition of the confining tube. The arrangement of soils in sequence from a coarse sand at the top of tubes to a fine silt loam at the bottom was found essential in order to fulfill distinct requirements. Percolation of water through the coarse top layer was rapid and expedited the water-process, yet provided an adequate reservior to catch sufficient moisture to dampen the tube to the bottom. A one-half inch lip above the soil surface provided a cup to catch water while sprinkling. Roots easily penetrated the upper coarser soils and moved into the finer soils below. The finer fraction of soils at the bottom retained moisture after the coarse surface soils dried out; this stimulated root growth downward. The finer soils at the bottom formed a dense soil plug which was necessary to prevent soil loss from the open bottom of the tube during transportation.

Generally, tube materials found to be sufficiently strong to remain intact in a continuously damp condition through the several-month-long root development period are slow to disintegrate in the ground following planting. The need to remove resistant tubes, reusable tubes, and split metal or plastic tubes would add complications to the mechanized planting process. A tube of fine plastic mesh did not effectively contain the potting soil nor inhibit horizontal penetration of roots into adjoining tubes. These tubes proved to be unmanageable and very difficult and slow to fill. Many potting tube materials were tested. The most satisfactory was found to be a thin absorbent paper tube reinforced with a ½ inch mesh plastic sleeve. This has proved to be an effective combination at reasonable cost and has apparently eliminated most disadvantages of previously tested materials.

Several prunings of foliage during the root development period were necessary to keep top growth under control, to conserve growing space and to reduce transpiration and foliage entanglement. Pruning of plant foliage, prior to loading for transport to the planting site, simplified the moving process. Likewise, it reduced foliage to an amount that a confined root system could reasonably support following planting under semiarid conditions.

A hardening period of several weeks in a lathhouse preceding planting was necessary to prevent sun burning and to acclimate tender greenhouse-nutured plants to desiccating winds, cold temperatures, and late spring frosts and snow storms.

Transportation of tubed planting stock has been relatively free of problems. In a properly designed cradle, tubed plants may be placed horizontally and stacked as many as fifteen plants high without any apparent damage. Approximately 300 plants of two-year-old stock or equivalent, stacked on the bed of a pickup truck, have been hauled 250 miles to a planting site without damage or difficulty, but protection from wind is essential.

Initial planting of tubed stock was done with a hog-nosed tiling shovel; later a one-man gasoline-powered soil auger with a 2½" diameter bit was used. Drilled planting holes then received the 2' deep tubelings. Air from around tubes was removed and essential soil contact made with a prying action on the handle of a hog-nosed tiling shovel inserted around the tube at three positions several inches distant from each plant.

All of the steps in the planting process were done in much the same way as a planting machine might do them. The planting machine, as proposed, is envisioned to be fed by a small trailer with containerized cartridges of tubelings in a prearranged sequence depending on terrain and landscape design requirements. The operator would drill the planting hole with a side-mounted auger and then actuate the planting basin scalper arm. The scalper would form a competition-free planting basin several feet in diameter. Following removal of the auger bit from the planting hole, the tubeling would be dropped in and securely set in place by the squeezing action of a 3-bladed circularly arranged device inserted around the tubeling. It has been estimated that such a machine using this tubeling system might plant from one to several shrubs per minute under good planting conditions. The speed of such a planting system coupled with increased survival of seedlings and reduction of labor costs involved, emphasize the practicality of this planting approach to Montana roadsides.

Job # 12. DRYLAND SHRUB PLANTING IN PLASTIC-LINED CONDENSATION TRAPS

INTRODUCTION - The tubeling method of shrub planting (Job # 11) illustrates an attempt to increase survival of shrubs in roadside plantings by placing the roots deep down into the moist soil. If roots of dryland transplants are not placed down in deep moist soil, then the alternative is to bring the deep soil moisture up to the root level of the transplants, or they generally cannot survive. In an effort to investigate such an approach, a dryland planting innovation was tested using plastic lined planting basins. The intent of these basins was to condense sub-soil moisture, not to catch precipitation. Plastic aprons of various shapes and colors have long been used in landscape planting to eliminate weed competition, to facilitate close cultivating and mowing, to improve appearance and even repel insects. However, their use has not primarily been intended to condense water vapor for plant use.

PROCEDURE - The principle used to pull up deep soil moisture is an old one - the "Big Flat Rock" effect - the same phenomenon used in desert survival to obtain emergency drinking water. A vigorous shrub is planted in a specially designed basin, approximately 15 square feet in area. Severe pruning is required. The basin is then lined with plastic and sealed by heeling in around the edge. Plant foliage is brought up through a hole in the plastic. The plastic liner thus reduces soil moisture evaporation in the vicinity of the planting. It collects saturated soil vapor carried above the surface where it condenses on the underside of the plastic liner. The condensate trickles down the taut plastic toward the plant and irrigates it.

Initial field tests were conducted in late spring of 1968, on the side of an interstate ramp at Huntley, Montana, a dry windy area, receiving 11.5 inches annual precipitation. Black and transparent plastic liners were used.

Rock weights were placed on the plastic liner above the low points in the basin floor close to the plants to prevent premature dropping of condensate at other than the desired location, and to keep the plastic liner stretched taut. Weights were also necessary to help prevent flapping of the liner by the wind. The flapping action loosens the airtight seal around the basin rim and may cause the liner to tear. Small slits were located beneath the rocks to drain entrapped precipitation. Additional condensation traps were constructed in similar manner at the Logan Research Area in 1969. In this second study temperature readings were taken inside the plastic lined basins during the hottest part of the summer and compared to the air temperature outside the basins. Moisture data was also derived by collecting the condensate from the under side of sample condensation traps. This was not a measure of total condensation within the basin area, but merely that condensate collected from the underside of the plastic liner.

RESULTS AND CONCLUSIONS - Several important findings regarding basin design were learned from these crude initial studies. Planting basins placed on a slope will fill with sediment from thunderstorms, necessitating cleaning if provision is not made to automatically flush the sediment from the basin. This can be accomplished by providing a low outlet on the downhill rim. In this way, if precipitation is heavy enough to wash sediment into the basin, it will be sufficient to move much of it out.

Sediment accumulation may kill many species of plants. Planting on a raised mound above the floor of the basin as shown in Figure reduced this problem.

The clear liner demonstrated how rapidly condensate appears; often droplets formed on the plastic before the basin construction job was completed. The clear plastic material lasted only one season before disintegrating, whereas the black showed no sign of weathering. It is expected to last several seasons.

The daily soil and moisture data taken from the Logan condensation trap study during a week in July is shown in Table 25. Table 26 contains similar weekly

Table 25. Daily temperature and moisture data from condensation traps at Logan, Montana[a] during one week in July, 1969.

Air Temperature F (Min)	Air Temperature F (Max)	Date of Reading	Inside Basin Temperature F[b] (Min)	Inside Basin Temperature F[b] (Max)	Time Period (hr)	Plastic Color	Condensate Collected (ml)
57	88	7/25/69	--	--	21½	Clear	73
		7/25/69	--	--	21½	Black	20
51	85	7/26/69	50	108	24	Clear	63
		7/26/69	52	103	24	Black	16
45	92	7/27/69	--	--	--	--	--
62	90	7/28/69	--	--	--	--	--
56	95	7/29/69	48	120	72	Clear	403
		7/29/69	50	110	72	Black	144
55	89	7/30/69	47	118	24	Clear	88
		7/30/69	46	102	24	Black	16
56	89	8/1/69	49	119	44	Clear	181
		8/1/69	51	113	44	Black	84

[a] Mean annual temperature - 46.5° F
Mean annual precipitation - 10.3 inches
Elevation 4,035 feet

[b] Temperatures recorded on basin bottom in shade

Table 26. Weekly temperature and moisture data from condensation traps at Logan, Montana[a], August, 1969.

Air Temperature F		Date of Reading	Inside Basin Temperature F[b]		Time Period	Plastic Color	Condensate Collected
(Min)	(Max)		(Min)	(Max)	(Days)		(ml)
42	100	8/k5/69	44	134	7	Clear	1109
		8/15/69	41	122	7	Black	319
44	96	8/22/69	34	131	7	Clear	2011
		8/22/69	38	114	7	Black	1016
37	101	8/30/69	42	128	8	Clear	2142
		8/30/69	32	126	8	Black	1568
31	92	9/5/69	24	122	6	Clear	2062
		9/5/69	22	110	6	Black	1242

a/ Mean annual temperature - 46.5° F
Mean annual precipitation - 12.3 inches

b/ Temperatures recorded on basin bottom in shade data for the month of August. There was an interesting difference in results between the clear and black plastic liners. Recorded daytime temperatures measured in late July reached 118° F under clear liners but only 102° F under black. Comparable night-time temperatures were 47° and 46° F, respectively. Direct comparisons of condensate collected from clear and black liners of adjacent similar sized basins was variable but demonstrated the clear liner to be more effective than the black.

The quantity of condensate produced in a stated period of time is variable and depends on the proximity and the amount of soil moisture reserves, the soil texture and color, the size of the basin, color of plastic, temperature differentials, and leaks in the plastic seal as well as distance to bedrock. An average of 343 milliliters of condensate per day were collected from a clear liner during a six-day interval in late summer. This accumulation in excess of one-half gallon seems more than ample to keep soil damp when soil moisture evaporation is controlled.

Data on survival of plants in condensation traps is premature at this time, but survival percentage appears to be approximately 70% on a total of 36 condensation trap plantings.

The principle of the condensation trap innovation in dryland planting of shrubs may be directly applicable to rapid stabilization of steep roadside slopes along highways and in interchanges. The use of black plastic eliminates the growth of weeds which are an obvious and expensive problem on interchange plantings. This approach to dryland planting should be pursued further to determine its adaptability to large mass plantings under plastic.

JOB # 13. "CHEMICAL MOWING" WITH MALEIC HYDRAZIDE:

INTRODUCTION - Species selection studies must consider potential savings offered by "chemical mowing". Consequently a "chemical mowing" study was conducted in conjunction with this revegetation project to determine if common species of roadside grasses would respond satisfactorily to maleic hydrazide under local conditions. If found susceptible, these species might then be included in reseeding projects and be controlled by spraying, thus reducing costly maintenance and mechanical mowing.

PROCEDURES - A series of trials was conducted using MH-30, a growth retarding compound containing maleic hydrazide and supplied by the U.S. Rubber Company. Initial test plots were established in 1966 at two locations, one on U.S. Highway 191 six miles west of Bozeman and one on U.S. Highway 10 three miles east of Bozeman. Both series were in a randomized block design. Each block consisted of a set of four plots -- one control and three intensities of chemical. Each plot measured 250' x 20'. The series west of Bozeman contained four blocks; the series east of Bozeman contained three blocks. The manufacturer's recommended application rate of MH-30 for the purpose of grass growth control was one and one-third gallons of MH-30 in 25 to 50 gallons of water per acre. The three treatment rates used were one and one-third gallons, one and two-third gallons, and two gallons of MH-30 in a total of 50 gallons of water per acre. The mixture was applied at a speed of eight miles per hour by a truck-mounted spray rig with boom. Spraying was done early on the morning of May 3, 1966, under ideal clear and calm conditions at a temperature of 55-60 degrees F. The series east of Bozeman was accidentally mowed before data could be collected. However, the abundant data obtained from the remaining series adequately represented the response of these grasses to the treatments used.

The effects of treatments in the plots west of Bozeman were recorded in August by measuring to the nearest inch the tallest culm (seedstock) and basal leaf of each of 100 plants of four species in each treatment plot. Culm incidence was also recorded as numbers of culmed plants in 100 observations per species per plot. All of these measurements were obtained to reflect the response of plants to treatments since it was anticipated that response in one category might be accompanied by a contradictory response in another. The four grass species considered in this study were orchard grass, Kentucky bluegrass, smooth bromegrass, and slender wheatgrass. The individual plants measured were selected by the step-point method. Results were tabulated by species and treatment. Standard Analysis of Variance techniques and Duncan's Multiple Range Test were used to compare means.

Upon analysis, it appeared that the range of application rates used in the initial MH-30 study was insufficient. Consequently a second chemical mowing study was conducted in September of 1968 to provide additional information regarding the use of MH-30. A randomized test plot arrangement similar to that in the initial study was designed and set out. Replicates again consisted of a set of four plots--one control and three intensities of chemical. However, the application rates were increased to 6.4 gallons, 8 gallons, and 13 gallons of MH-30 in 50 gallons of water per acre. The same method of application was used. Weather was cool and partly cloudy, soil was moist, and general conditions were ideal for chemical application.

Effects of treatments were recorded in early August, 1969, as done in the previous study, by measuring to the nearest inch the tallest culm and basal leaf of each of 100 plants of four species in each treatment plot.

The four species measured were the same as those in the first study. Culm incidence data was not taken in the second study.

RESULTS AND RECOMMENDATIONS - The tabulated results of the analysis of the first MH-30 study are shown in Tables 27, 28, and 29.

Leaf Height: A satisfactory response in inhibited leaf growth did not result from any of the treatments used among the species tested, although Kentucky bluegrass approached a desirable inhibition. Table227 shows that mean leaf heights usually remained far in excess of a 6 to 10 inch growth range considered as maximum to eliminate the need for mowing. Table 27 also shows a significant difference in the case of Kentucky bluegrass between the check plot and treated plots, but no difference among chemical rates. Orchard grass and slender wheatgrass were not affected by any of the rates used.

Culm Height: Table 28 shows that for Kentucky bluegrass, smooth bromegrass, and slender wheatgrass, a significant reduction in culm height was associated with the chemical treatments; but as with leaf heights, no difference was apparent among the rates used. Orchard grass response was erratic and less conclusive, yet the one and two-thirds gallon rate of MH-30 produced culm heights significantly lower than the check.

Culm Incidence: Mean culm incidence varied greatly among species, treatments, and replicates. Kentucky bluegrass apparently was not affected because culm incidence was 100 percent in all treatments. The other species showed the lowest incidence of culms with the one and two-thirds MH-30 rate, but there were no clear trends of treatment response demonstrated.

Table 27. Mean leaf height (inches) as affected by MH-30 by species.

Treatment (gallons/acre)		Orchard grass	Kentucky bluegrass	Smooth bromegrass	Slender wheatgrass
Control	0	13.62 a[1/]	11.27 a	17.26 a	14.02 a
MH-30	1 1/3	13.64 a	8.92 b	13.11 c	11.58 a
MH-30	1 2/3	13.36 a	9.35 b	14.28 bc	12.76 a
MH-30	2	12.89 a	9.31 b	15.44 ab	12.06 a

Table 28. Mean culm height (inches) as affected by MH-30 by species.

Treatment (gallons/acre)		Orchard grass	Kentucky bluegrass	Smooth bromegrass	Slender wheatgrass
Control	0	30.08 a[1/]	19.32 a	32.99 a	27.00 a
MH-30	1 1/3	27.79 ab	16.03 b	26.32 b	22.90 b
MH-30	1 2/3	26.25 b	15.56 b	28.28 b	21.50 b
MH-30	2	28.04 ab	16.46 b	28.11 b	23.40 b

Table 29. Mean culm incidence as affected by MH-30 species (Numbers of culmed plants in 100 observations per species per plot).

Treatment (gallons/acre)		Orchard grass	Kentucky bluegrass	Smooth bromegrass	Slender wheatgrass
Control	0	65.50 a[1/]	100 a	79.00 a	68.00 b
MH-30	1 1/3	61.25 c	100 a	38.25 c	69.50 a
MH-30	1 2/3	48.25 d	100 a	27.50 d	57.00 c
MH-30	2	63.50 b	100 a	41.50 b	70.00 a

[1/] Means within species with one or more letters in common are not significantly different at ($P \leq .05$) level of probability according to Duncan's Multiple Range Test. (Duncan, 1955).

SUMMARY:- Response to MH-30 treatment rates as reflected by leaf heights of grass species tested in the initial study was variable and inconclusive. Two species, orchard grass and slender wheatgrass, were not significantly affected by the rates of treatments used. Culm heights were significantly inhibited in all species with MH-30 treatment, but with orchard grass only the one and two-thirds gallon rate was significantly lower than the check. With the other species, the chemical concentrations used made no difference. Although the culm incidence was reduced by treatment in two species, it was not significantly reduced in a third, and increased in the fourth species.

Based on the lack of difference shown among the rates of MH-30 used, it was assumed that the span of rates applied in this study was not broad enough to reflect the susceptibility of the species tested. Results obtained suggested that the experiment be repeated using heavier chemical application rates. Also, to avoid the inconsistencies due to the difference in growth among species on an early spring spray application, a fall application was advised.

The second MH-30 study was conducted in an effort to provide more concrete results than the initial study. Sites were sprayed in the fall when all grass species had reached maturity.

The results of the second study are even less conclusive of any concrete effects of MH-30 than were those of the initial study. It is recommended that maleic hydrazide not be used as a means of "chemical mowing" in Montana.

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APPENDIX

Appendix A

LIST OF SPECIES INCLUDED IN THIS REPORT

Common Name	Scientific Name
Alfalfa	Medicago sativa
Alkali sacaton	Sporobolus airoides
Alpine vetch	Astragalus alpinus
Artic willow	Salix alpina
Astragalus species	Astragalus sp.
Annual wheatgrass	Agropyron triticeum
Basin wildrye	Elymus cinereus
Beardless wildrye	Elymus triticoides
Big sagebrush	Artemisia tridentata
Bitterbrush	Purshia tridentata
Black medic	Medicago lupulina
Blue grama	Bouteloua gracilis
Bluebunch wheatgrass	Agropyron spicatum
Bog birch	Betula glandulosa
Broom snakeweed	Gutierrezia sarothrae
Buckthorn	Rhamnus catharticus
Buffalograss	Buchloe dactyloides
Bulbous bluegrass	Poa bulbosa
California poppy	Papaver sp.
Canada bluegrass	Poa compressa
Canada wildrye	Elymus canadensis
Canadian clematis	Clematis serratifolia
Canby bluegrass	Poa canbyi
Cheatgrass	Bromus tectorum
Chewings fescue	Festuca commutata
Chokecherry	Prunus virginiana
Cicer milkvetch	Astragalus cicer
Common caragana	Caragana arborescens
Common juniper	Juniperus communis
Coralberry	Symphoricarpos orbiculatus
Crested wheatgrass	Agropyron cristatum
Cudweed sagewort	Artemisia ludoviciana
Cyanus	Cyanus sp.
Double dianthus	Dianthus sp.
Draylar bluegrass	Poa glaucantha
Fairway crested wheatgrass	Agropyron cristatum
Field sagewort	Artemisia campestris
Firebush	Kochia scoparia
Fourwing saltbush	Atriplex confertifolia
Foxtail barley	Hordeum jubatum
Fringed sagewort	Artemisia frigida

Common Name	Scientific Name
Gaillardia	Gaillardia sp.
Gardner saltbush	Atriplex gardnerii
Goldenrod	Solidago missouriensis
Goldenweed	Haplopappus sp.
Greasewood	Sarcobatus vermiculatus
Green needlegrass	Stipa viridula
Green sagewort	Artemisia dracunculoides
Gumweed, curlycup	Grindelia squarrosa
Green bristlegrass	Setaria viridis
Hairy goldenaster	Chrysopsis villosa
Hard fescue	Festuca duriuscula
Hawthorn	Crateagus douglasii
Hops	Humulus lupulus
Horizontal juniper	Juniperus horizontalis
Indian ricegrass	Oryzopsis hymenoides
Japanese brome	Bromus japonicus
Kentucky bluegrass	Poa pratensis
Kinnikinnik	Arctostaphylos uva-ursi
Little bluestem	Andropogon scoparius
Lupine	Lupinus sp.
Mandan ricegrass	Stipa x Oryzopsis
Matrimony vine	Lycium halimifolium
Maximowitz caragana	Caragana maximowitziana
Meadow barley	Hordeum brachyantherum
Meadow fescue	Festuca elatior
Meadow foxtail	Alopecurus pratensis
Mock orange	Philadelphus lewisii
Moss rose	Portulaca grandiflora
Mountain ash	Sorbus scopulina
Mountain moahogany	Cercocarpus ledifolius
Mustard	Cruciferae family
Nasturium	Nasturium sp.
Needleandthread	Stipa comata
Needleleaf sedge	Carex eleocharis
Ninebark	Physocarpus malvaceus
Nomad alfalfa	Medicago sativa
Nuttalls alkaligrass	Puccinellia nuttalliana
Nuttalls saltbush	Atriplex gardnerii
Orchardgrass	Dactylis glomerata
Oregon grape	Berberis repens
Orenburg alfalfa	Medicago falcata

Common Name	Scientific Name
Pampian bromegrass	Bromus brevis
Penngift crownvetch	Coronilla varia
Perrennial ryegrass	Lolium perenne
Phlox	Phlox sp.
Pigweed	Amaranthus graecizans
Plains pricklypear	Opuntia polyacantha
Prairie rose	Rosa arkansana
Prairie sandreed	Calamovilfa longifolia
Purple willow	Salix purpurea
Pygmy caragana	Caragana pygamaea
Quackgrass	Agropyron repens
Red fescue	Festuca rubra
Red stemmed dogwood	Cornus stolonifera
Red threeawn	Aristida longesita
Rocky Mountain juniper	Juniperus scopulorum
Rubber rabbitbrush	Chrysothamnus nauseosus
Russian knapweed	Centaurea repens
Russian thistle	Salsola kali
Sainfoin Eski	Onobrychis (viciaefolia)
Saltgrass	Distichlis stricta
Sand dropseed	Sporobolus cryptandrus
Sandbar willow	Salix exigua
Sandberg bluegrass	Poa secunda
Sea buckthorn	Hippophae rhamnoides
Siberian wheatgrass	Agropyron sibiricum
Silver fleece vine	Polygonum aubertii
Silver sagebrush	Artemisia cana
Silverberry	Elaeagnus argentea
Single dianthus	Dianthus sp.
Sixweeks fescue	Festuca octoflora
Slender wheatgrass	Agropyron trachycaulum
Smooth bromegrass	Bromus inermis
Smooth sumac	Rhus glabra
Snowberry	Symphoricarpos occidentalis
Squirrel tail	Sitanion hystrix
Strawberry	Fragaria sp.
Sudangrass	Sorghum vulgare 'sudanensis'
Sweetclover	Melilotus officinalis
Streambank wheatgrass	Agropyron riparium
Tall fescue	Festuca arundinacea
Tall oatgrass	Arrhenatherum elatius
Tall wheatgrass	Agropyron elongatum
Tamarix	Tamarix sp.
Thickspike wheatgrass	Agropyron dasystachyum
Threadleaf sedge	Carex filifolia

Common Name	Scientific Name
Three-leaf sumac	Rhus trilobata
Ticklegrass	Agrostis scabra
Timothy	Phleum pratense
Tumblegrass	Schedonnardus paniculatus
Virginia creeper	Parthenocissus quinquefólia
Waxleaf penstemon	Penstemon nitidus
Western wheatgrass	Agrophyron smithii
Western white clematis	Clematis ligusticifolia
White-flowered prairie clover	Petalostemon oligophyllus
White willow	Salix alba
Wild lettuce	Lactuca sp.
Wild rose	Rosa sp.
Willow	Salix sp.
Winterfat	Eurotia lanata
Woods rose	Rosa woodsii
Yellow hop clover	Trifolium agrarium
Yellow pea	Thermopsis montana
Yucca	Yucca glanca